AIRCRAFT EQUIPMENT DIVISION

CR 150957

SOLID POLYMER ELECTROLYTE (SPE) FUEL CELL TECHNOLOGY

NASA/JSC CONTRACT NAS 9-14345

PROGRAM REVIEW

(PHASE II)

APRIL 29, 1976

(NASA-CR-150957) SOLID POLYMER ELECTROLYTE (SPE) FUEL CELL TECHNOLOGY, PROGRAM REVIEW, PHASE 2 (General Electric Co., Wilmington, Mass.) 40 p HC A03/MF A01 CSCL 10A

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G3/44 55051

DIRECT ENERGY CONVERSION PROGRAMS
50 FORDHAM ROAD
WILMINGTON, MASSACHUSETTS 01887

GENERAL ELECTRIC

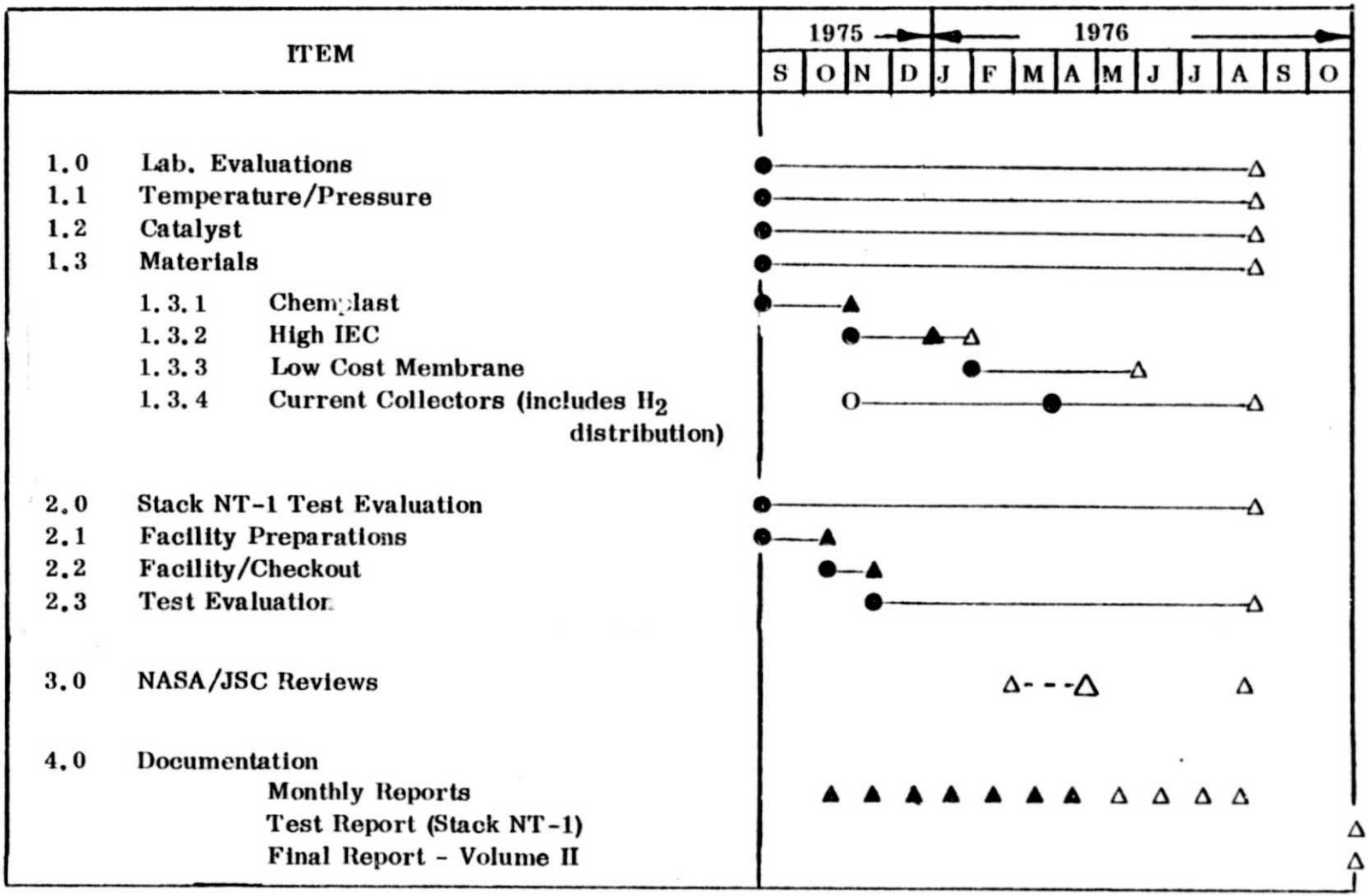
SPE FUEL CELL TECHNOLOGY PROGRAM

PURPOSE:

To advance the SPE Fuel Cell Technology in the following target areas:

- Reduced Fuel Cell Costs
- Reduced Fuel Cell Weight
- Improved Fuel Cell Efficiency
- Increased Systems Compatibility

MILESTONE CHART

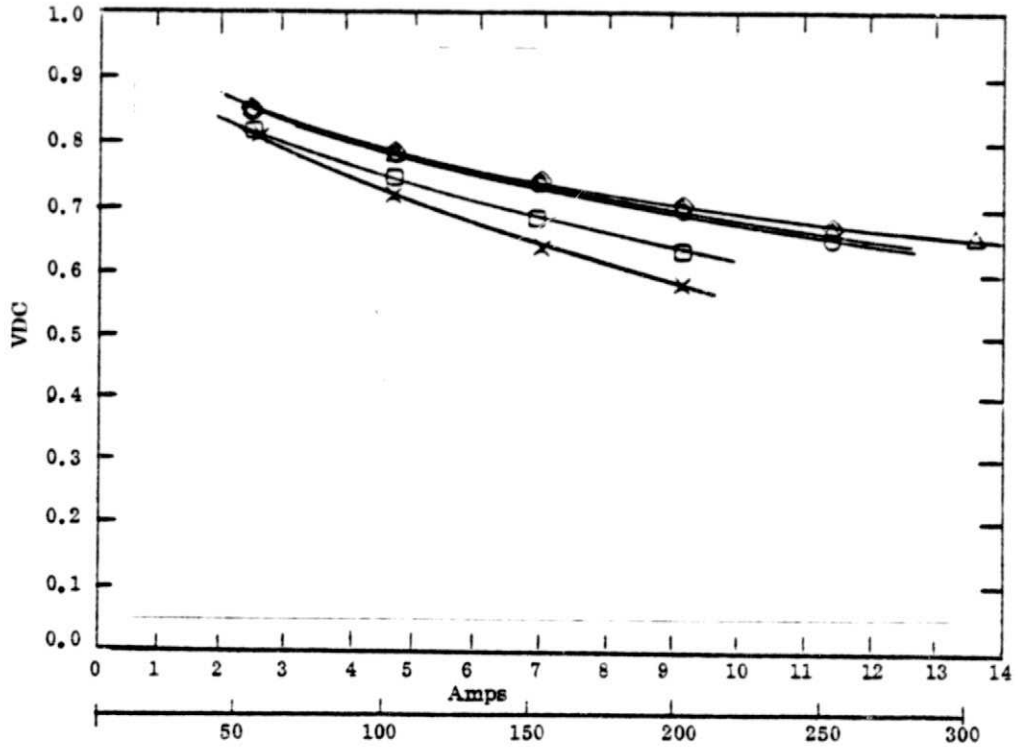


NASA/JSC Technology Program Phase II

A Summary of the 1975 Baseline Cell Configuration is as Follows:

- Solid Polymer Electrolyte
  - duPont's Nafion ®
  - 5 Mils Thick
  - 35-40% H_2O
  - 1200 E.W.
  - Platinized

- Anode
  - 4 Grams/Ft^2 Metal Loading
  - 12.5% T-30
  - 1/4 Inch Stand Pipe
  - 3 Mil Niobium Screen
  - Chemplast Wetproofing



Fuel Cell NT-6-2 (1975 Baseline)

◇ - O_2/H_2 (120°F) R = 0.0067 Ohm

△ - O_2/H_2 (165°F) R = 0.0065 Ohm

□ - Air/H_2 (165°F) R = 0.007 Ohm
2.5 x Air Stoich

○ - O_2/H_2 (25% CO_2 - 10 PPM CO)
1.25 x stoich (165°F) R = 0.0065 Ohm

× - O_2/H_2 (25% CO_2 - 0.3 % CO)
1.25 x stoich (165°F) R = 0.0065 Ohm

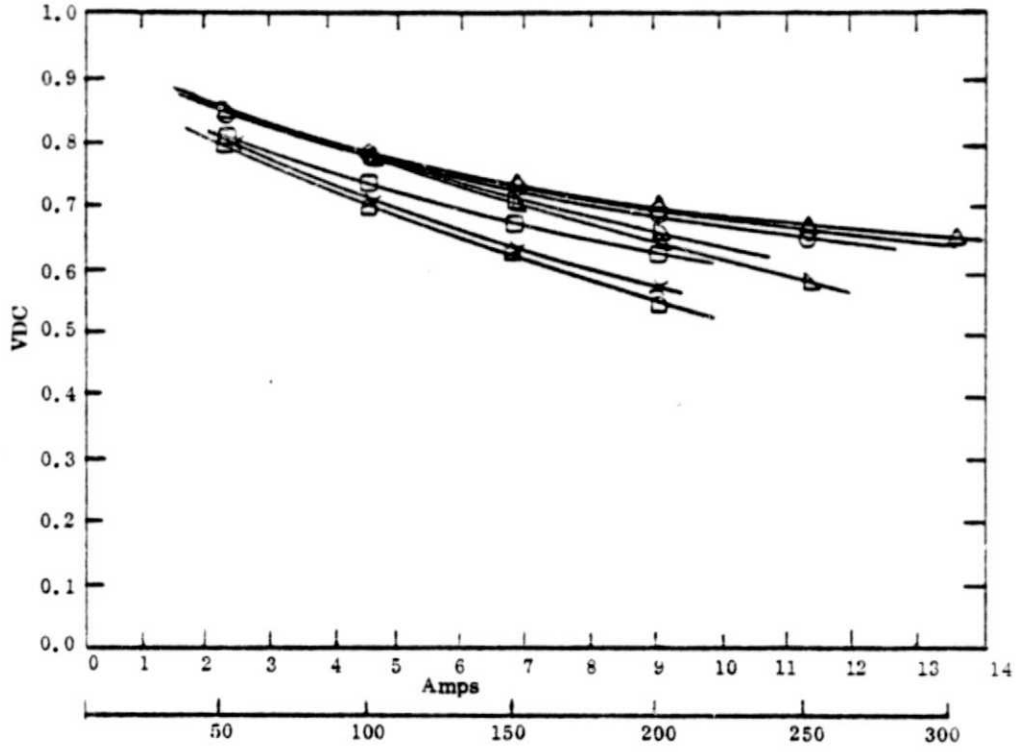
TASK 1.1 TEMPERATURE AND PRESSURE PERFORMANCE

PURPOSE:

To Evaluate Variations of the 1975 Baseline Cell Configuration at Higher Temperature and Pressure Conditions.

A Total of Three Cells Have Been Evaluated Under This Task.

Fuel Cell Number NASA (Phase II) Technology-Subtask-Cell NT(II) - X - X	Deviation from 1975 Baseline Fuel Cell	Performance Variance from 1975 Baseline Fuel Cell									
		O_2/H_2 100 ASF at 120°F VDC (0.703)	O_2/H_2 200 ASF at 120°F VDC (0.703)	O_2/H_2 100 ASF at 165°F VDC (0.786)	O_2/H_2 200 ASF at 165°F VDC (0.712)	Air/H_2 100 ASF at 165°F VDC (0.736)	Air/H_2 200 ASF at 165°F VDC (0.626)	O_2/H_2 (10 PPM CO) 100 ASF at 165°F VDC (0.780)	O_2/H_2 (10 PPM CO 200 ASF at 165°F VDC (0.695)	O_2/H_2 (.3% CO) 100 ASF at 165°F VDC (0.693)	O_2/H_2 (.3% CO) 200 ASF at 165°F VDC (0.566)
NT(II) - 1 - 1	10 Mil SPE 6/0 - 3/0 Niobium Anode Screen Assembly	-0.004	-0.058	-0.013	-0.053	-0.040	-0.090	-	-	-	-
NT(II) - 1 - 2	10 Mil SPE 6/0 - 3/0 Niobium Anode Screen Assembly	-	-	-0.034	-0.080	-	-	-	-	-	-
NT(II) - 1 - 3	1975 Baseline in High Current Density Facility	-	-	-	-	-	-	-	-	-	-



Fuel Cell NT-6-2 (1975 Baseline)

◇ - O_2/H_2 (120°F) R = 0.0067 Ohm

△ - O_2/H_2 (165°F) R = 0.0065 Ohm

□ - Air/H_2 (165°F) R = 0.007 Ohm
2.5 x Air Stoich

○ - O_2/H_2 (25% CO_2 - 10 PPM CO)
1.25 x Stoich (165°F) R = 0.0065 Ohm

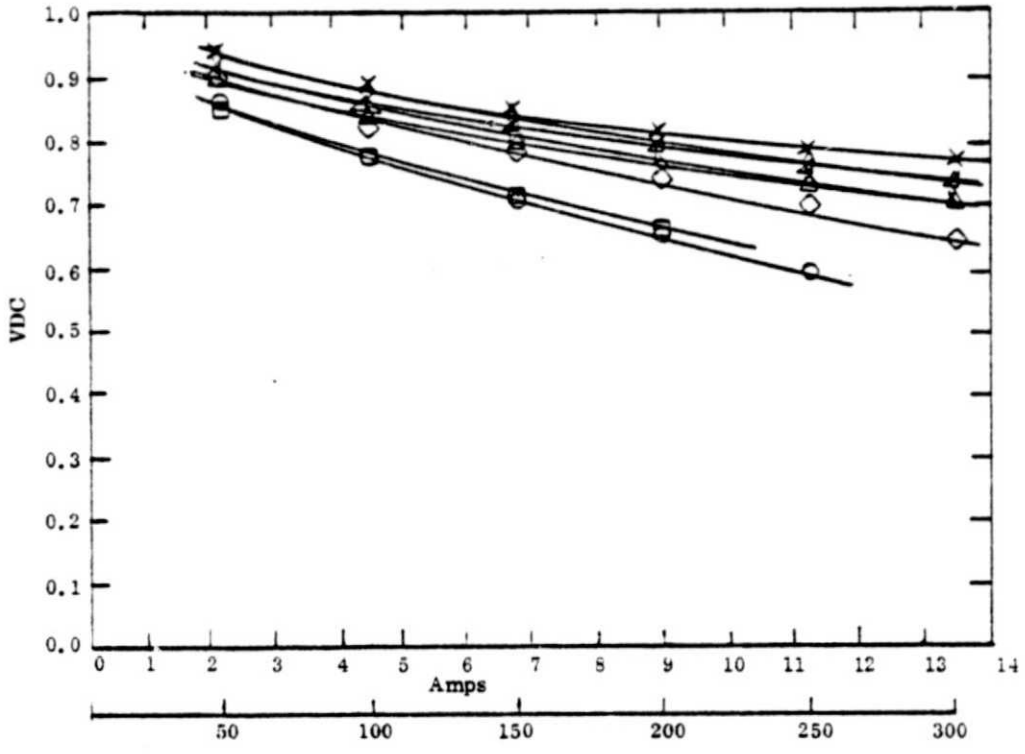
× - O_2/H_2 (25% CO_2 - 0.3% CO)
1.25 x Stoich (165°F) R = 0.0065 Ohm

Fuel Cell NT(II)-1-1 (6/0 Anode-10 Mil)

▷ - O_2/H_2 (120°F) R = 0.0073 Ohm

▷ - O_2/H_2 (165°F) R = 0.0089 Ohm

▷ - Air/H_2 (165°F) R = 0.0108 Ohm
2.5 x Stoich Air



Fuel Cell NT(II)-1-1 (6/0 Anode - 10 Mil)

○ - O_2/H_2 (120°F) R = 0.0093 Ohm O_2 Press. - 37" H_2O ΔP - 17" H_2O

□ - O_2/H_2 (165°F) R = 0.0089 Ohm O_2 Press. - 37" H_2O ΔP - 17" H_2O

◇ - O_2/H_2 (165°F) R = 0.0086 Ohm O_2 Press. - 15 Psig ΔP - 17" H_2O

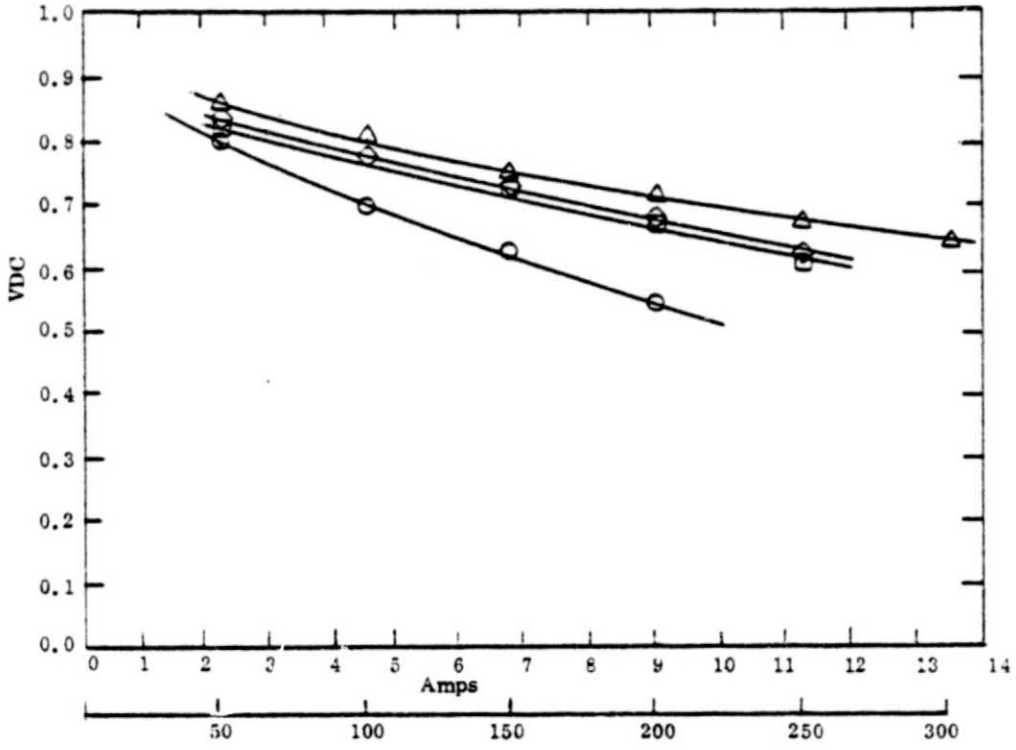
△ - O_2/H_2 (165°F) R = 0.0069 Ohm O_2 Press. - 15 Psig ΔP - 90" H_2O

▷ - O_2/H_2 (165°F) R = 0.0107 Ohm O_2 Press. - 30 Psig ΔP - 15" H_2O

◁ - O_2/H_2 (165°F) R = 0.0068 Ohm O_2 Press. - 30 Psig ΔP - 90" H_2O

◊ - O_2/H_2 (165°F) R = 0.010 Ohm O_2 Press. - 45 Psig ΔP - 17" H_2O

× - O_2/H_2 (165°F) R = 0.0068 Ohm O_2 Press. - 45 Psig ΔP - 90" H_2O



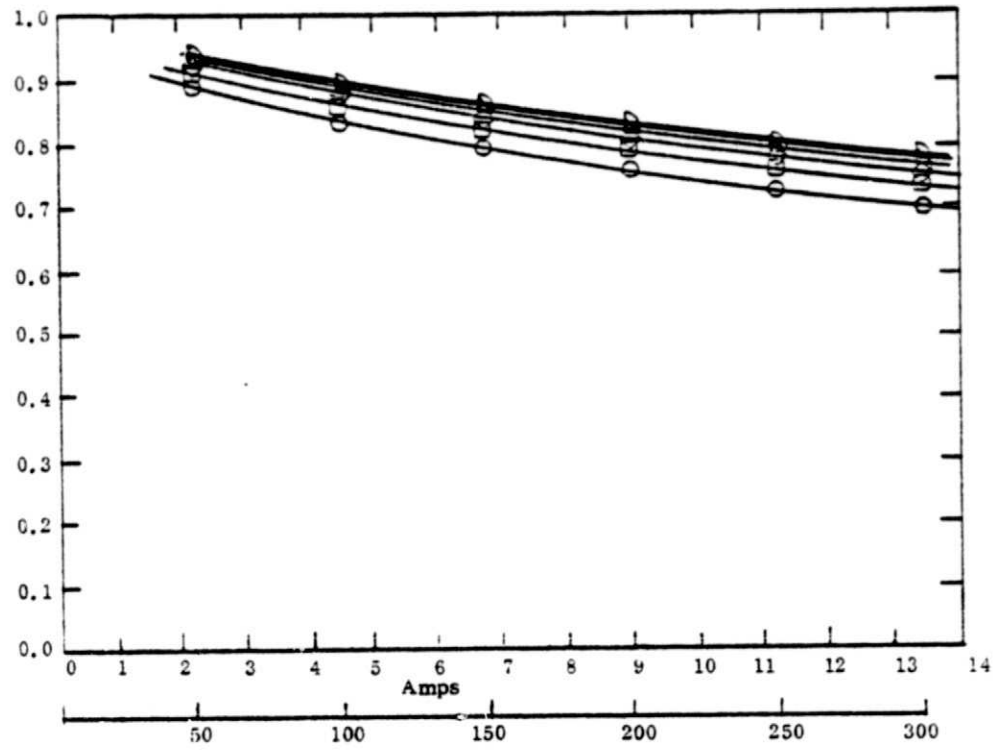
Fuel Cell NT(II)-1-1 (6/0 Anode - 10 Mil)

○ - Air/H_2 (165°F) R = 0.0108 Ohm Air Press. - 37" H_2O ΔP - 17" H_2O
2.5 x Stoich Air

□ - Air/H_2 (165°F) R = 0.011 Ohm Air Press. - 15 Psig ΔP - 17" H_2O
2.5 x Stoich Air

◇ - Air/H_2 (165°F) R = 0.0069 Ohm Air Press. - 15 Psig ΔP - 90" H_2O
2.5 x Stoich Air

△ - Air/H_2 (165°F) R = 0.0069 Ohm Air Press. - 45 Psig ΔP - 90" H_2O
2.5 x Stoich Air



Fuel Cell NT (II) - 1 - 2 (6/0 Anode - 10 Mil)

○ - O_2/H_2 (165°F) R=0.007 Ohm, O_2 Pressure 15 psig ΔP-90"H_2O

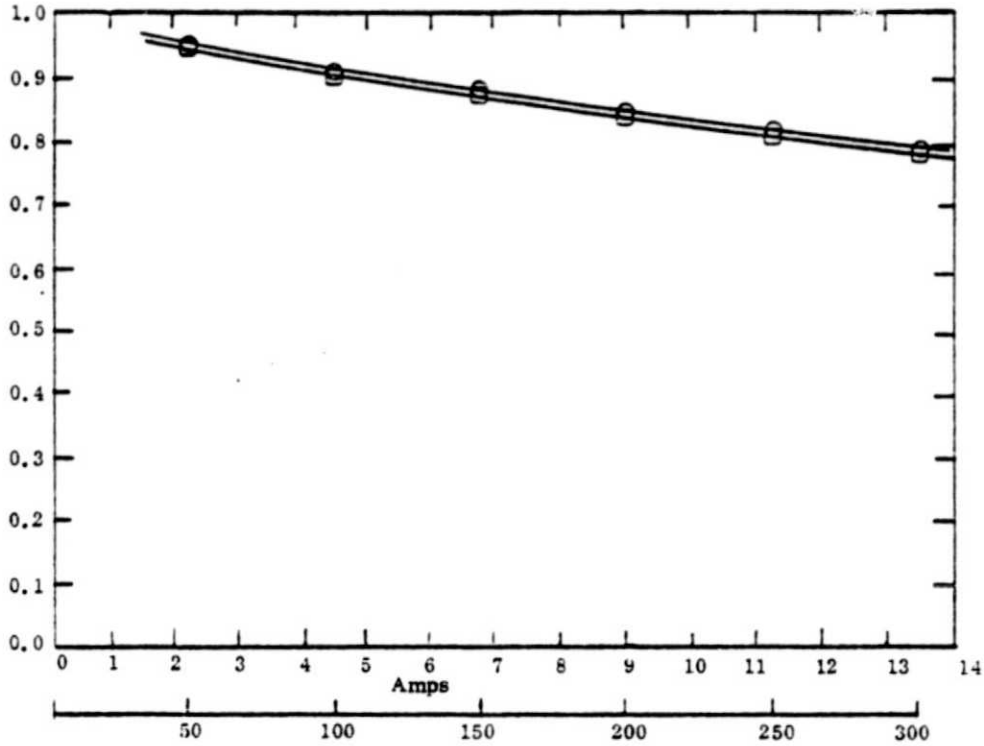
□ - O_2/H_2 (165°F) R=0.007 Ohm, O_2 Pressure 30 psig ΔP-90"H_2O

◇ - O_2/H_2 (165°F) R=0.007 Ohm, O_2 Pressure 45 psig ΔP-90"H_2O

△ - O_2/H_2 (165°F) R=0.007 Ohm, O_2 Pressure 60 psig ΔP-90"H_2O

◺ - O_2/H_2 (165°F) R=0.007 Ohm, O_2 Pressure 75 psig ΔP-90"H_2O

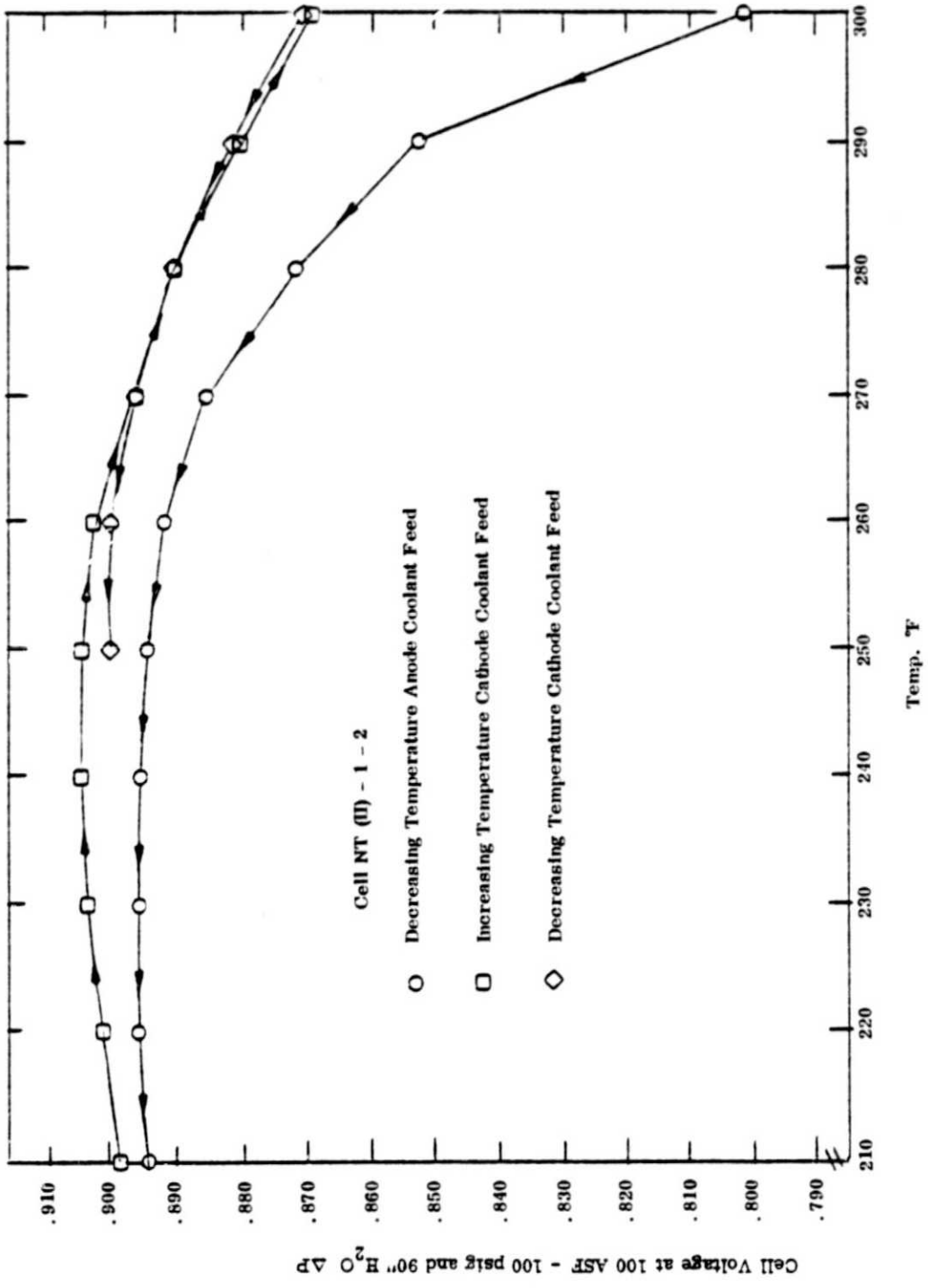
◺ - O_2/H_2 (165°F) R=0.007 Ohm, O_2 Pressure 85 psig ΔP-90"H_2O

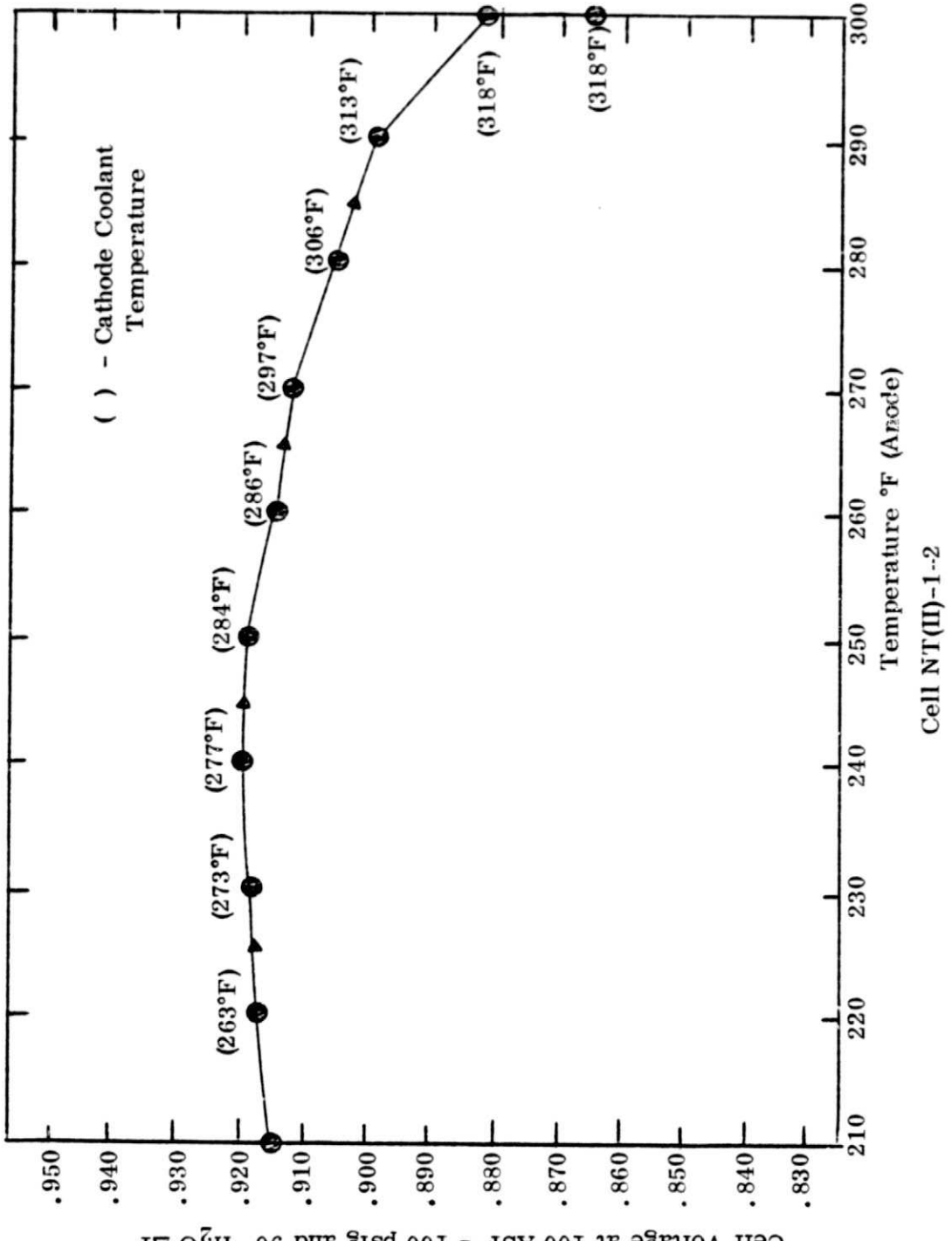


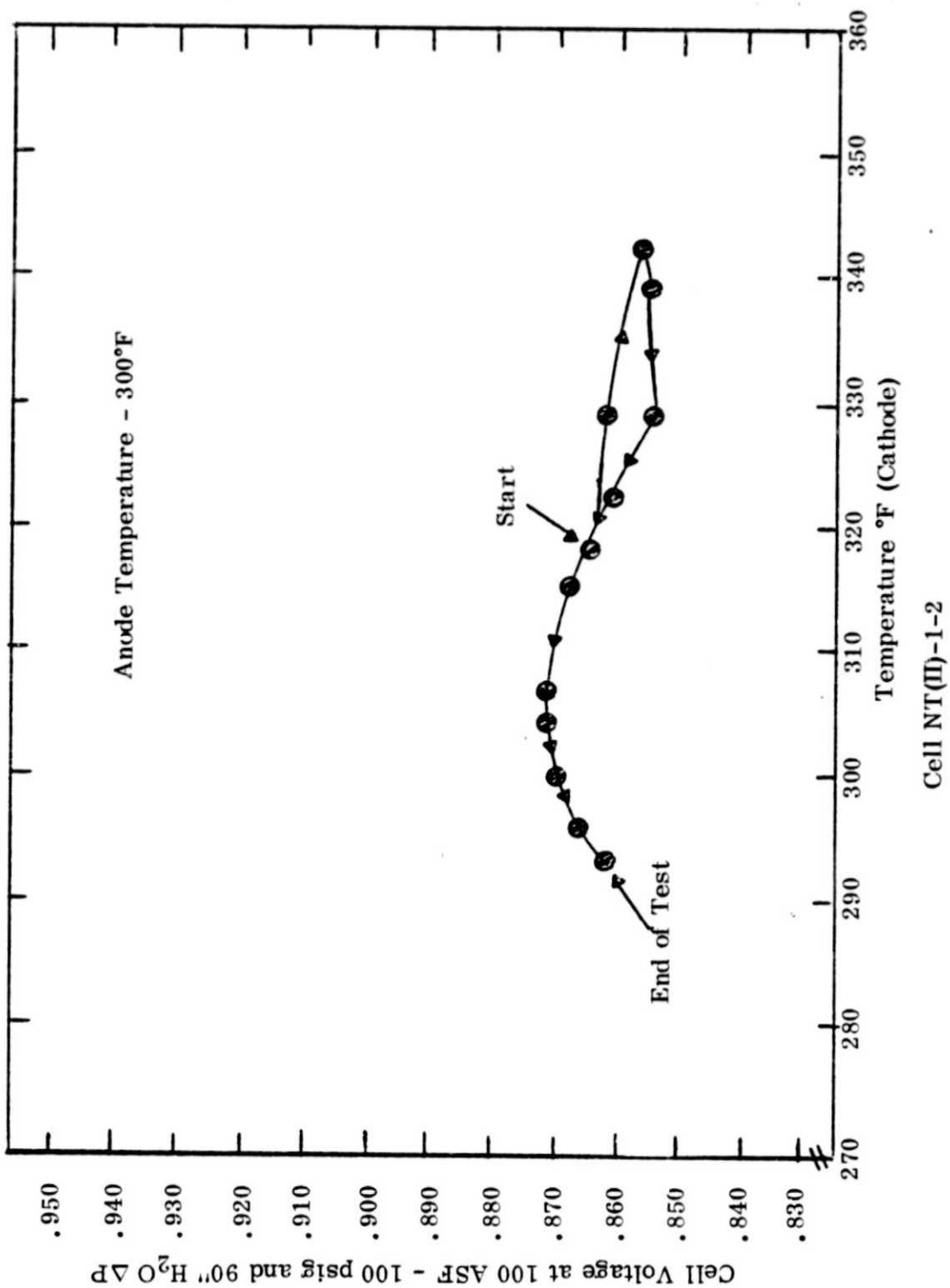
Fuel Cell NT (II)-1-2 (6/0 Anode -10 Mil)

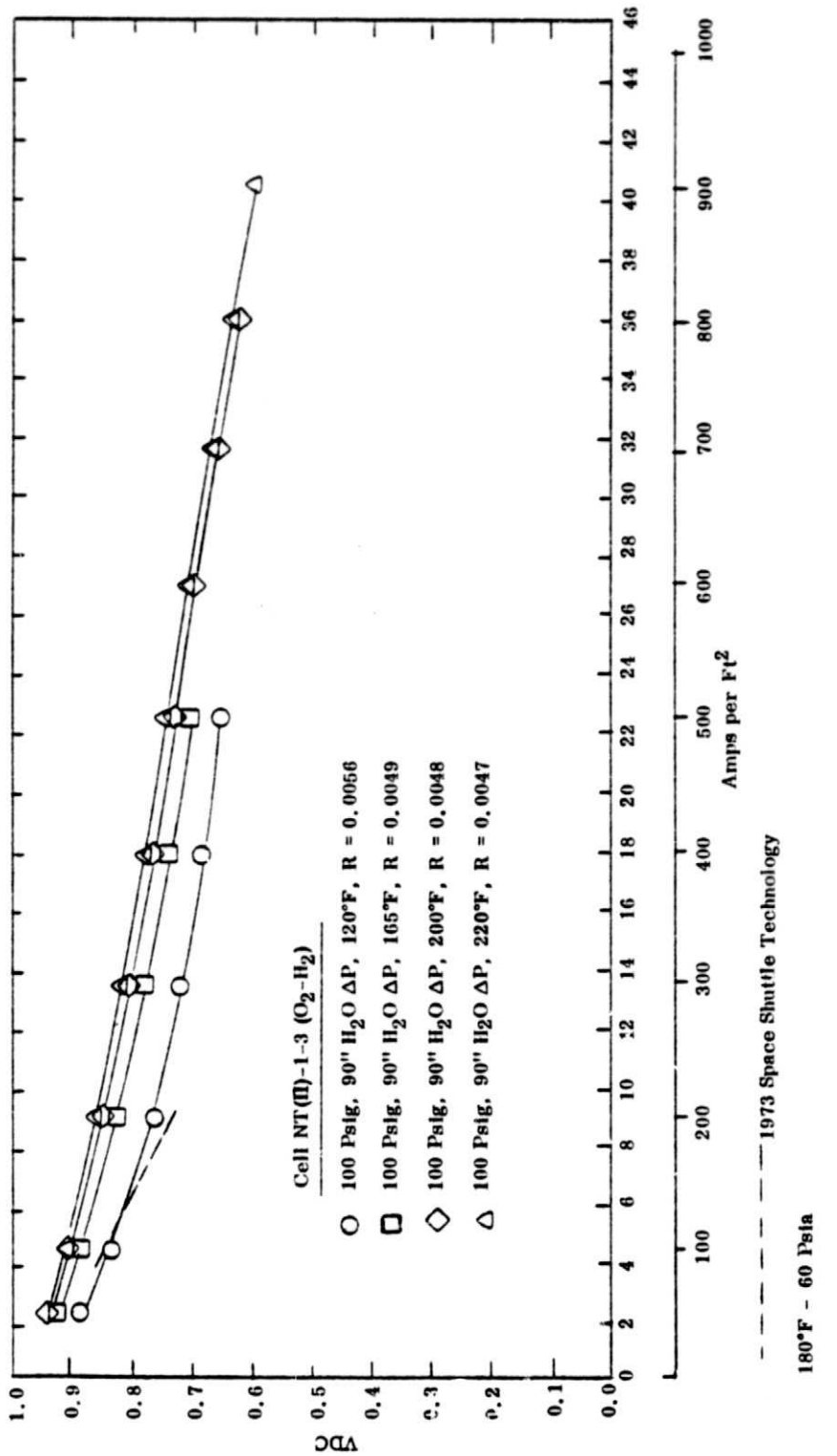
○ - O_2/H_2 (220°F) R=0.0061 Ohm, O_2 Pressure 85 psig, ΔP-90"

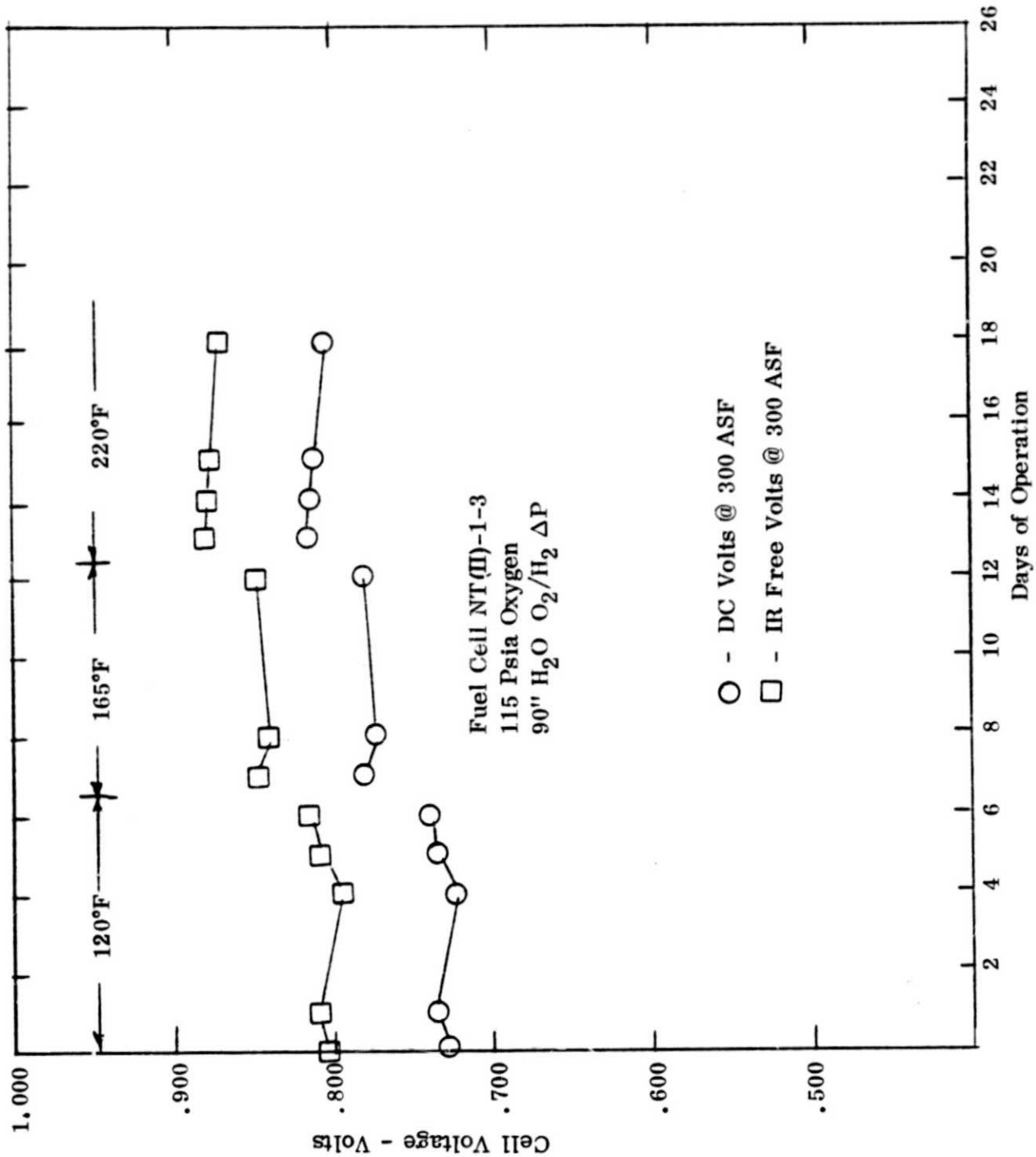
□ - O_2/H_2 (250°) R= 0.0059 Ohm, O_2 Pressure 85 psig, ΔP-90"


Cell NT (II) - 1 - 2
Decreasing Temperature Anode Coolant Feed
Increasing Temperature Cathode Coolant Feed
Decreasing Temperature Cathode Coolant Feed
Temp. °F
Cell Voltage at 100 ASF - 100 psig and 90" H_2O ΔP
.916
.900
.890
.880
.870
.860
.850
.840
.830
.820
.810
.800
.790
210
220
230
240
250
260
270
280
290
300


( ) - Cathode Coolant Temperature
(263°F)
(273°F)
(277°F)
(284°F)
(286°F)
(297°F)
(306°F)
(313°F)
(318°F)
(318°F)
Cell NT(II)-1-2
Temperature °F (Anode)
Cell Voltage at 100 ASF - 100 psig and 90% H_2O ΔP
.950
.940
.930
.920
.910
.900
.890
.880
.870
.860
.850
.840
.830
210
220
230
240
250
260
270
280
290
300


Anode Temperature - 300°F
Start
End of Test
Cell Voltage at 100 ASF - 100 psig and 90° H_2O ΔP
.950
.940
.930
.920
.910
.900
.890
.880
.870
.860
.850
.840
.830
270
280
290
300
310
320
330
340
350
360
Temperature °F (Cathode)
Cell NT(II)-1-2


Cell NT(II)-1-3 (O_2-H_2)
○ 100 Psig, 90" H_2O ΔP, 120°F, R = 0.0056
□ 100 Psig, 90" H_2O ΔP, 165°F, R = 0.0049
◇ 100 Psig, 90" H_2O ΔP, 200°F, R = 0.0048
△ 100 Psig, 90" H_2O ΔP, 220°F, R = 0.0047
VDC
Amps per Ft^2
1973 Space Shuttle Technology
180°F - 60 Psia


Cell Voltage - Volts
1.000
.900
.800
.700
.600
.500
2
4
6
8
10
12
14
16
18
20
22
24
26
Days of Operation
120°F
165°F
220°F
Fuel Cell NT(II)-1-3
115 Psia Oxygen
90" H_2O O_2/H_2 ΔP
○ - DC Volts @ 300 ASF
□ - IR Free Volts @ 300 ASF

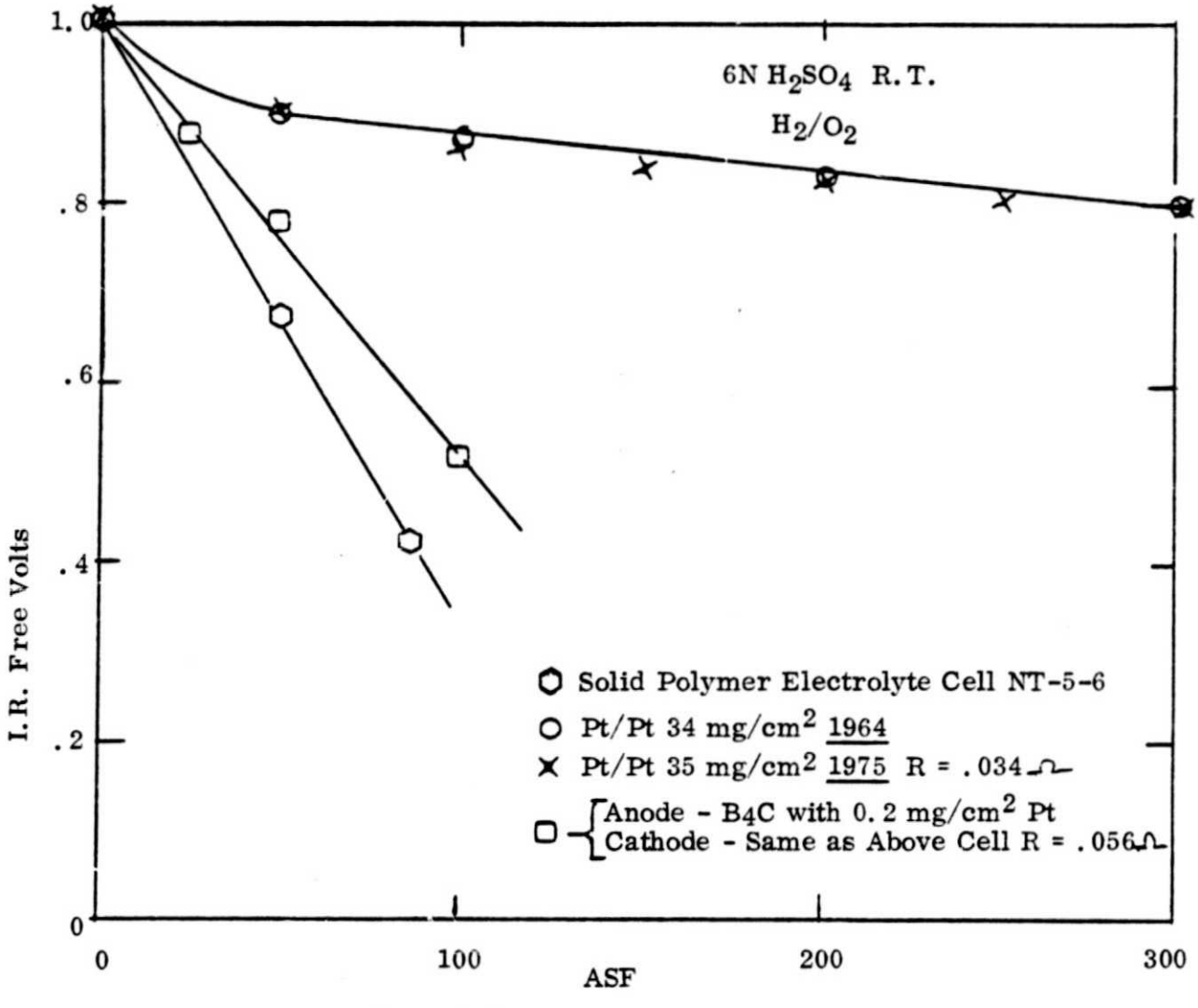
TASK 1.2 CATALYST REDUCTION PERFORMANCE

PURPOSE:

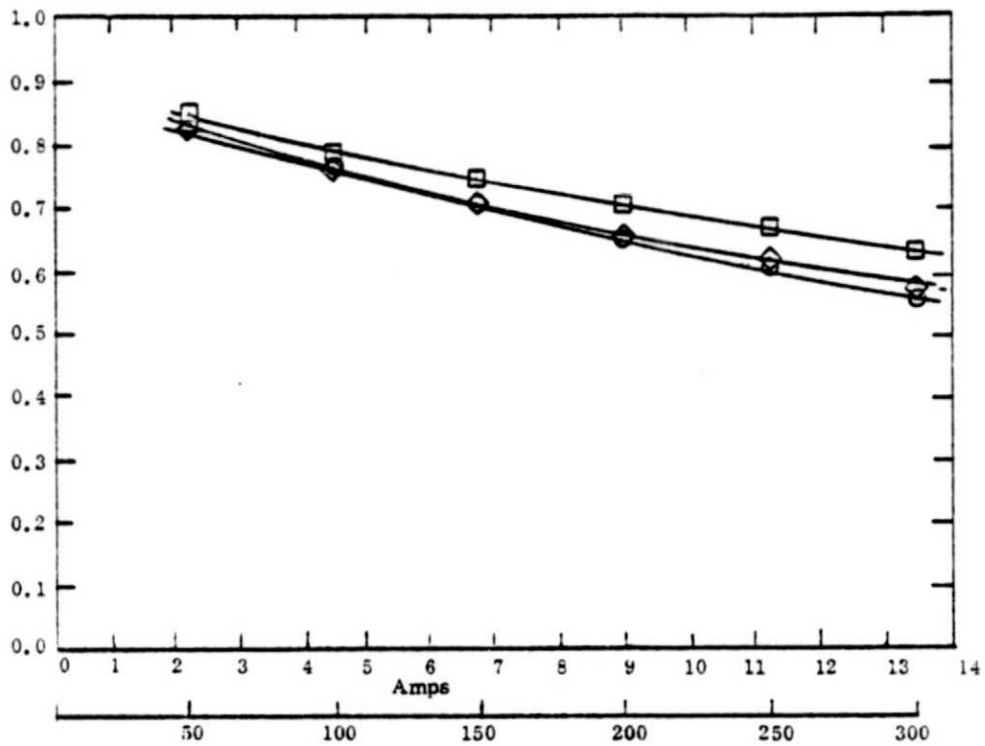
To Demonstrate Techniques of Lowering Catalyst Noble Metal Content Without Loss of Output Performance.

Two Liquid Acid Cells and Five SPE Cells Were Fabricated and Evaluated as Part of This Task.

Fuel Cell Number NASA (Phase II) Technology-Subtask-Cell NT(II) - X - X	Deviation from 1975 Baseline Fuel Cell	Performance Variance from 1975 Baseline Fuel Cell									
		O_2/H_2 100 ASF at 120°F VDC (0.781)	O_2/H_2 200 ASF at 120°F VDC (0.703)	O_2/H_2 100 ASF at 165°F VDC (0.786)	O_2/H_2 200 ASF at 165°F VDC (0.712)	Air/H_2 100 ASF at 165°F VDC (0.736)	Air/H_2 200 ASF at 165°F VDC (0.626)	O_2/H_2 (10 PPM CO) 100 ASF at 165°F VDC (0.780)	O_2/H_2 (10 PPM CO) 200 ASF at 165°F VDC (0.695)	O_2/H_2 (.3% CO) 100ASF at 165°F VDC (0.693)	O_2/H_2 (.3% CO) 200 ASF at 165°F VDC (0.566)
NT(II)-2-1	10 Mil SPE 28% H_2O, Unplatinized Membrane, 1 mg/cm^2 Pt Anode	-0.016	-0.042	-0.016	-0.042	-	-	-	-	-	-
NT(II)-2-2	10 Mil SPE 28% H_2O, Unplatinized Membrane, 1 mg/cm^2 Pt with 3 mg/cm^2 Graphite Anode (Layered)	+0.009	+10.005	+0.011	-0.002	-	-	-	-	-	-
NT(II)-2-3	10 Mil SPE 28% H_2O, Unplatinized Membrane, 1 mg/cm^2 Pt Mixed With 3 Mg per cm^2 Graphite Anode	-0.022	-0.037	-0.014	-0.039	-	-	-	-	-	-
NT(II)-2-4	10 Mil SPE 28% H_2O, Unplatinized Membrane 0.02 mg/cm^2 Pt Sputtered on 3 mg/cm^2 Graphite Anode	-0.017	-0.055	-0.034	-0.112	-	-	-	-	-	-
NT(II)-2-5	10 Mil SPE 28% H_2O, Unplatinized Membrane 0.25 mg/cm^2 Pt and 3.75 mg/cm^2 Graphite layers	-0.011	-0.035	-0.051	-0.153	-	-	-	-	-	-



I. R. Free Voltage vs. Current Density



Fuel Cell NT(II)-2-1 (1 mg/cm^2 Pt Anode)

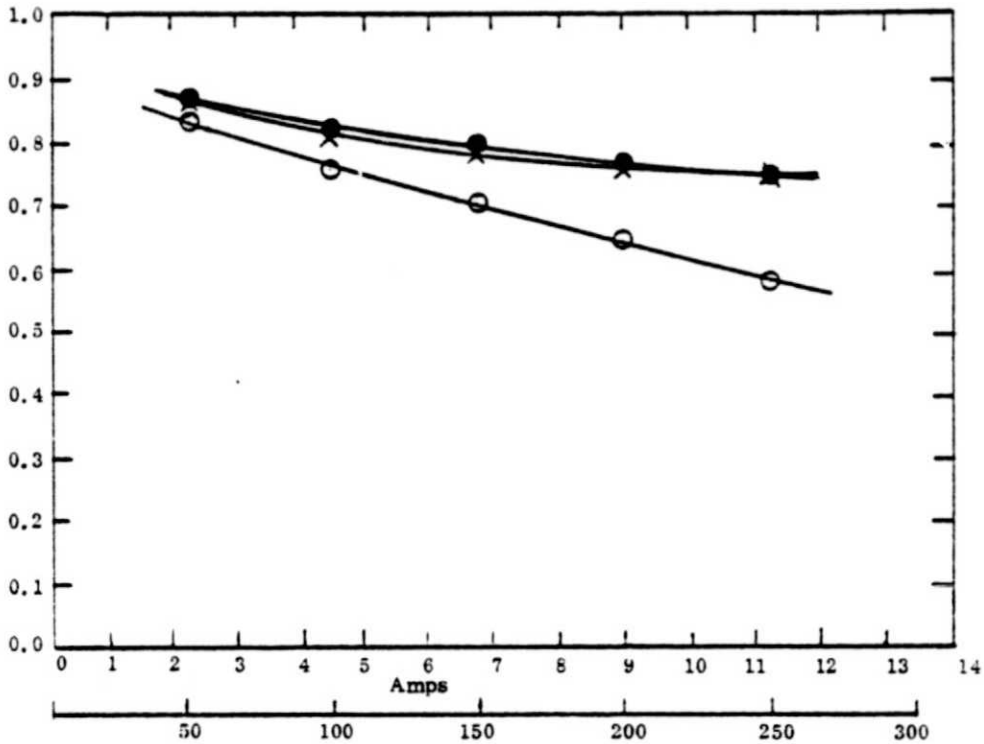
O - O_2/H_2 (120°F) R = 0.0105 Ohm

Fuel Cell NT(II)-2-2 (1 mg/cm^2 Pt - 3 mg/cm^2 Graphite Layered Anode)

□ - O_2/H_2 (120°F) R = 0.009 Ohm

Fuel Cell NT(II)-2-3 (1 mg/cm^2 Pt - 3 mg/cm^2 Graphite Mixed Anode)

◇ - O_2/H_2 (120°F) R = 0.0115 Ohm



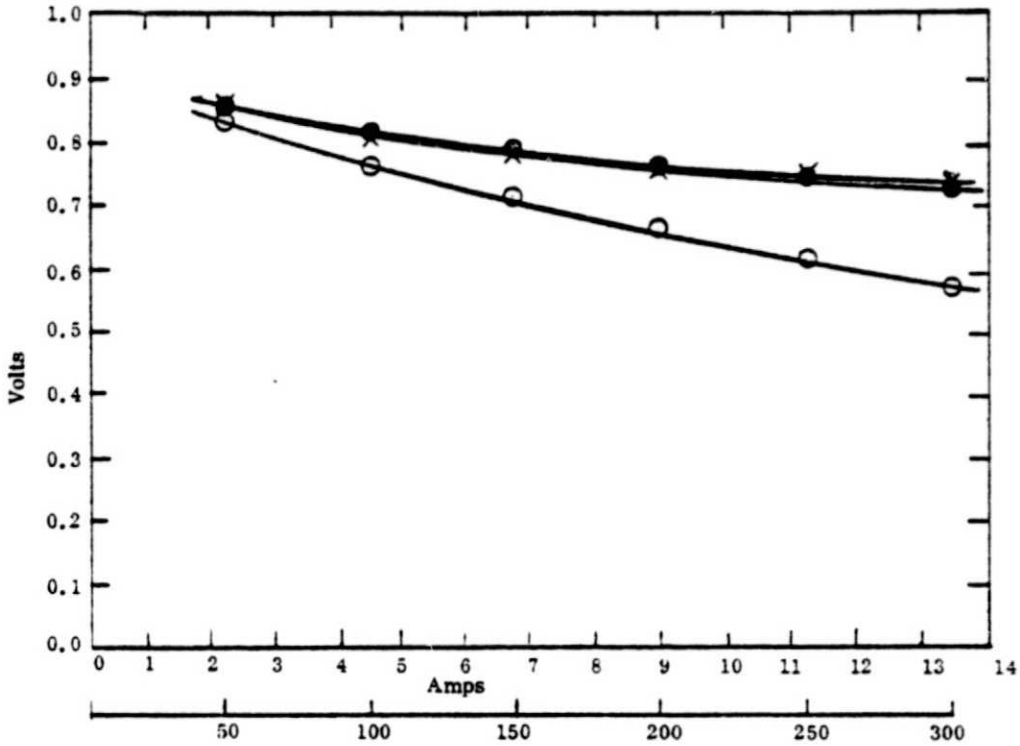
Fuel Cell NT(II)-2-4 (0.02 mg/cm^2 Pt. Sputtered Anode)

○ - DCV O_2/H_2 (120°F) R = 0.0145 Ohm

● - IR Free O_2/H_2 (120°F)

Fuel Cell NT-6-2 (1975 Baseline)

× - IR Free O_2/H_2 (120°F)



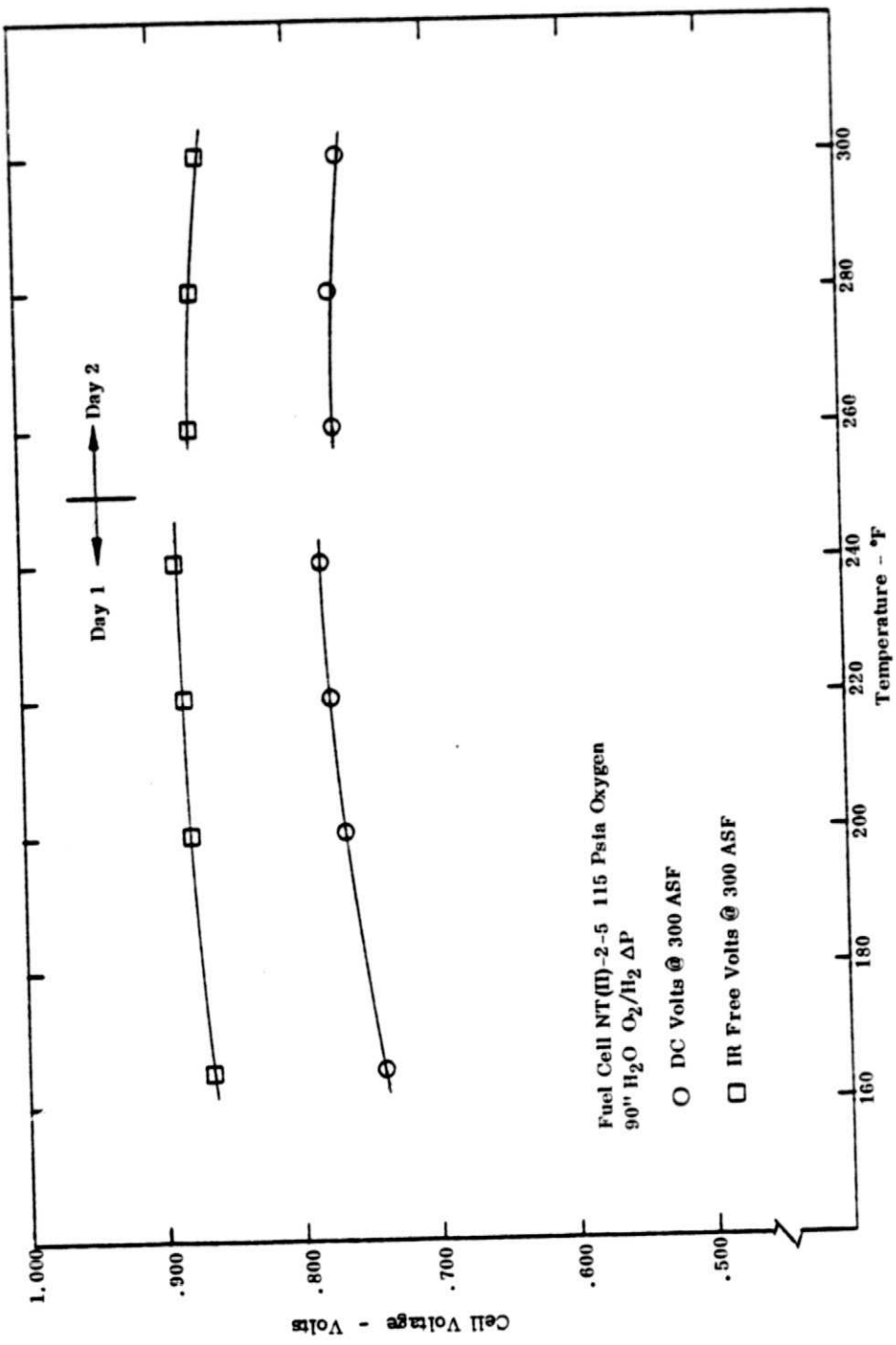
Fuel Cell NT(II)-2-5 (0.25 mg/cm^2 Pt. in Anode)

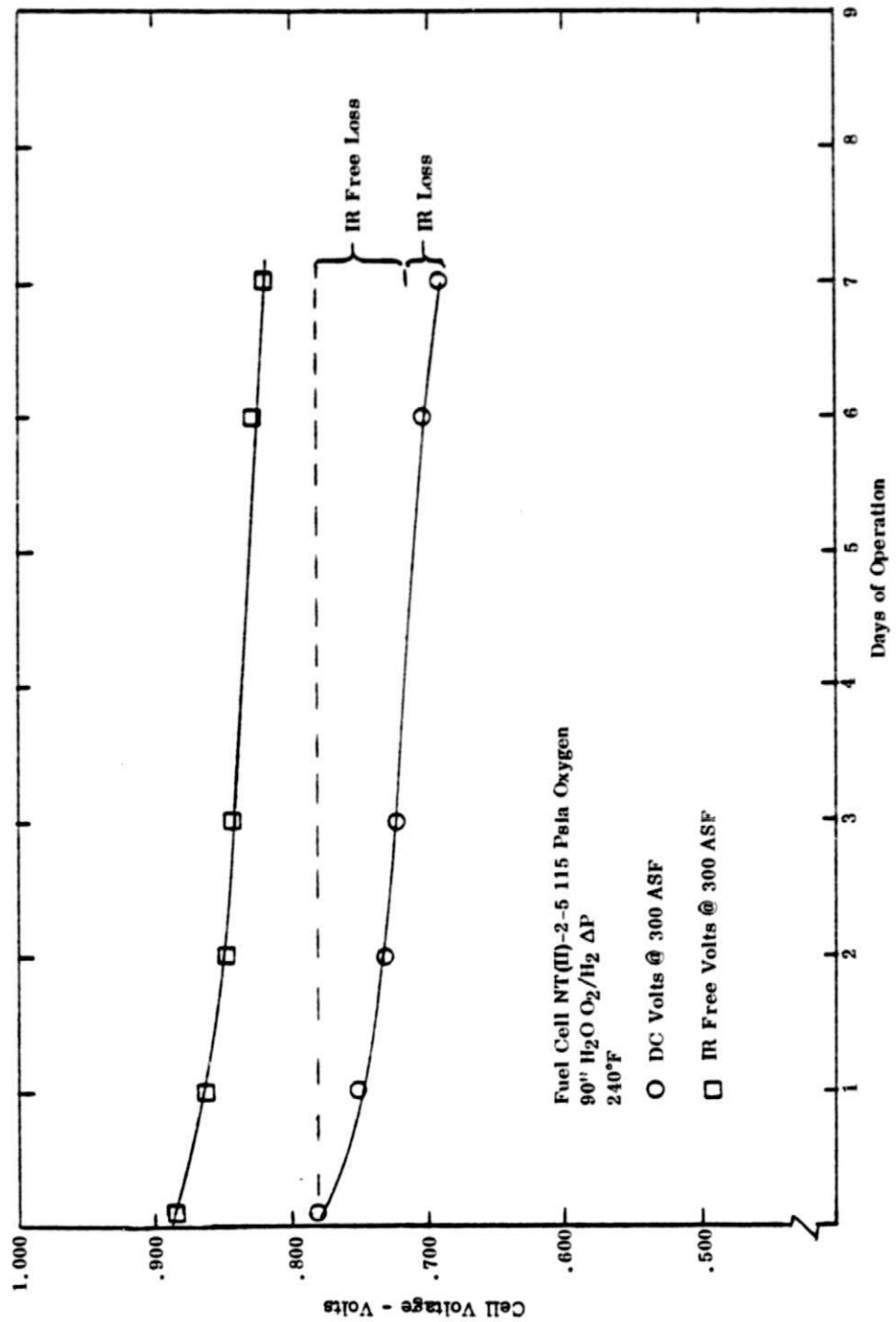
○ D.C.V. O_2/H_2 (120°F) R = 0.0113 Ohm

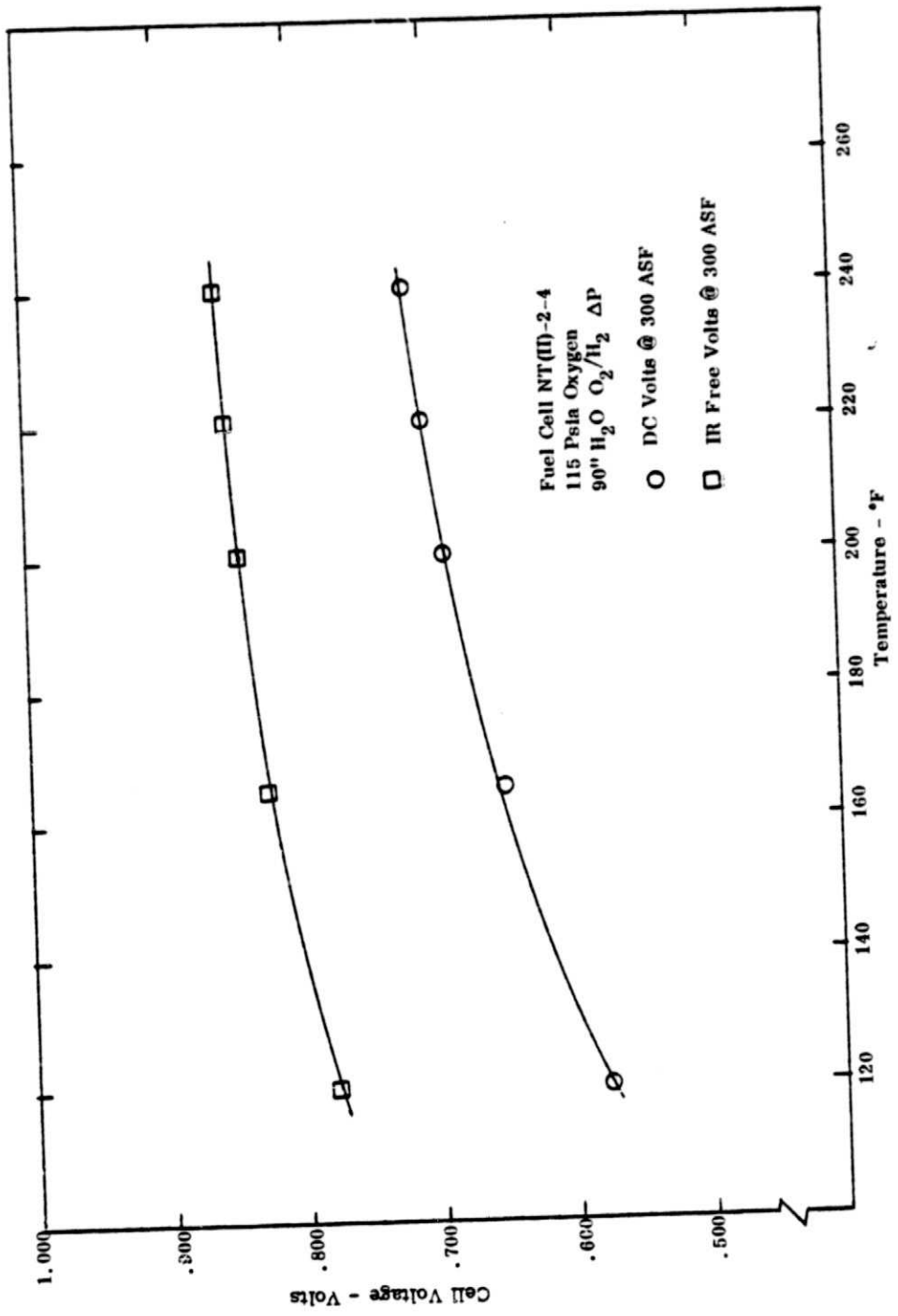
● IR Free O_2/H_2 (120°F)

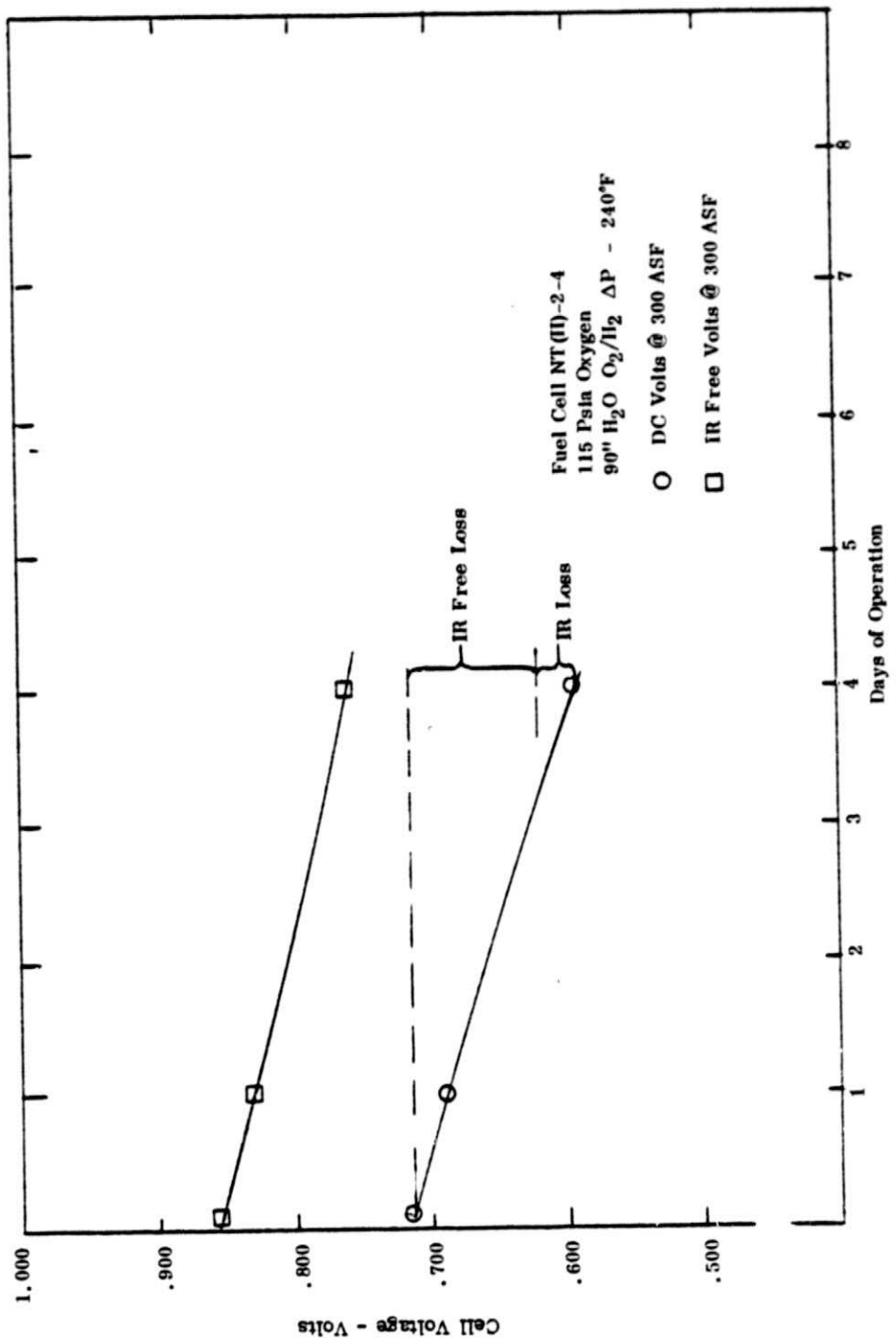
Fuel Cell NT-6-2 (1975 Baseline)

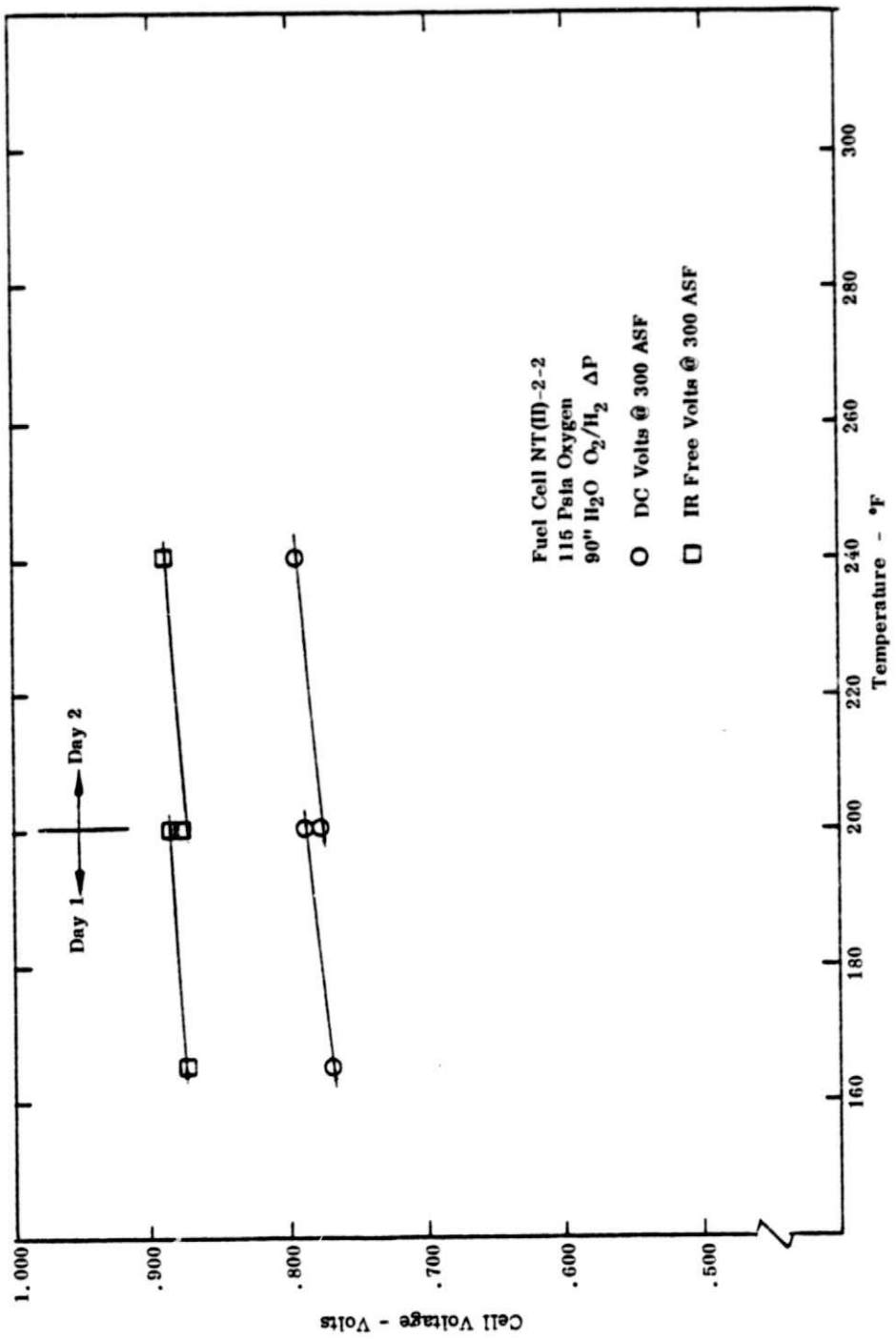
× IR Free O_2/H_2 (120°F)

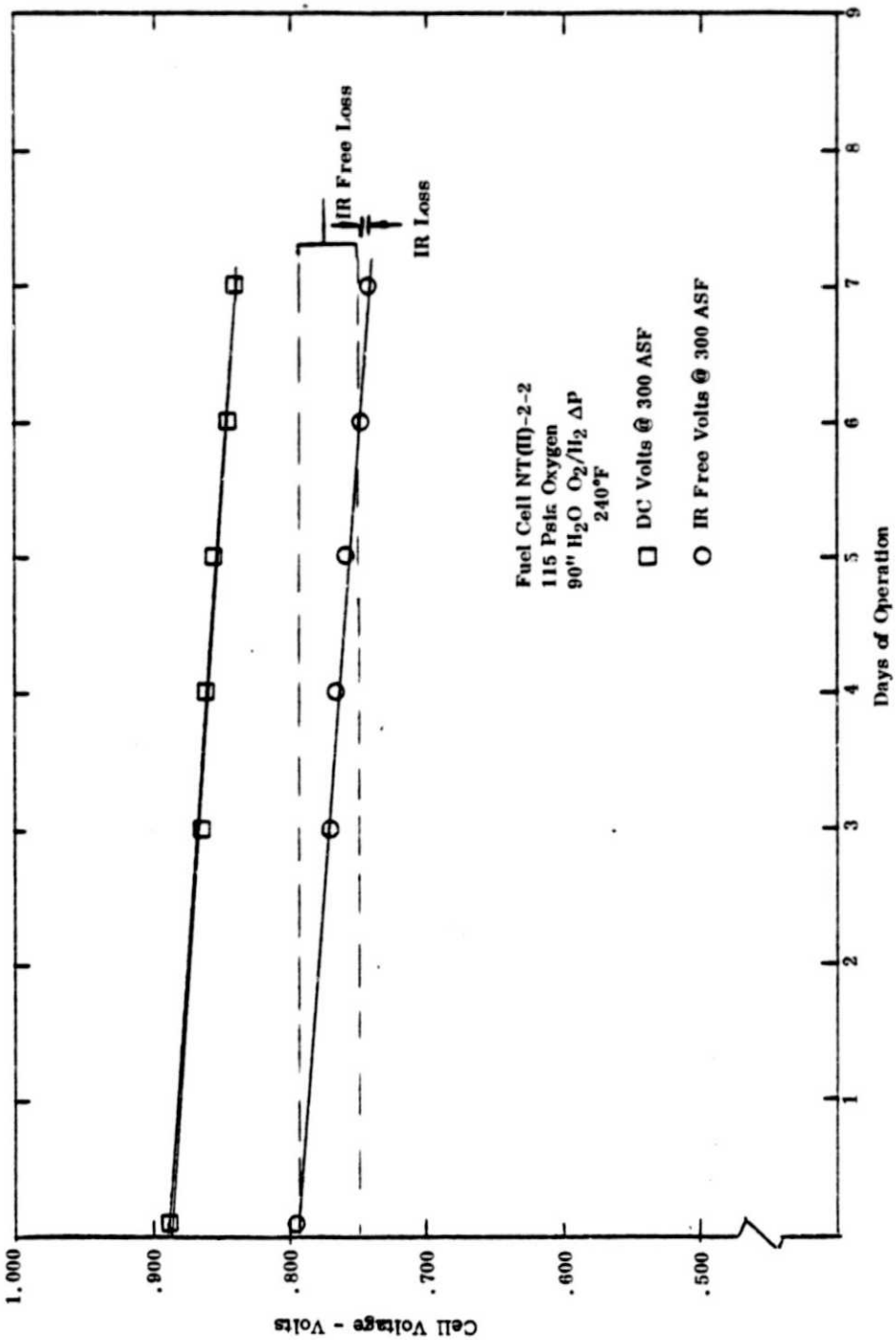

Cell Voltage - Volts
1.000
.900
.800
.700
.600
.500
160
180
200
220
240
260
280
300
Temperature - °F
Day 1
Day 2
Fuel Cell NT(II)-2-5 115 Psia Oxygen
90" H_2O O_2/H_2 ΔP
O DC Volts @ 300 ASF
□ IR Free Volts @ 300 ASF

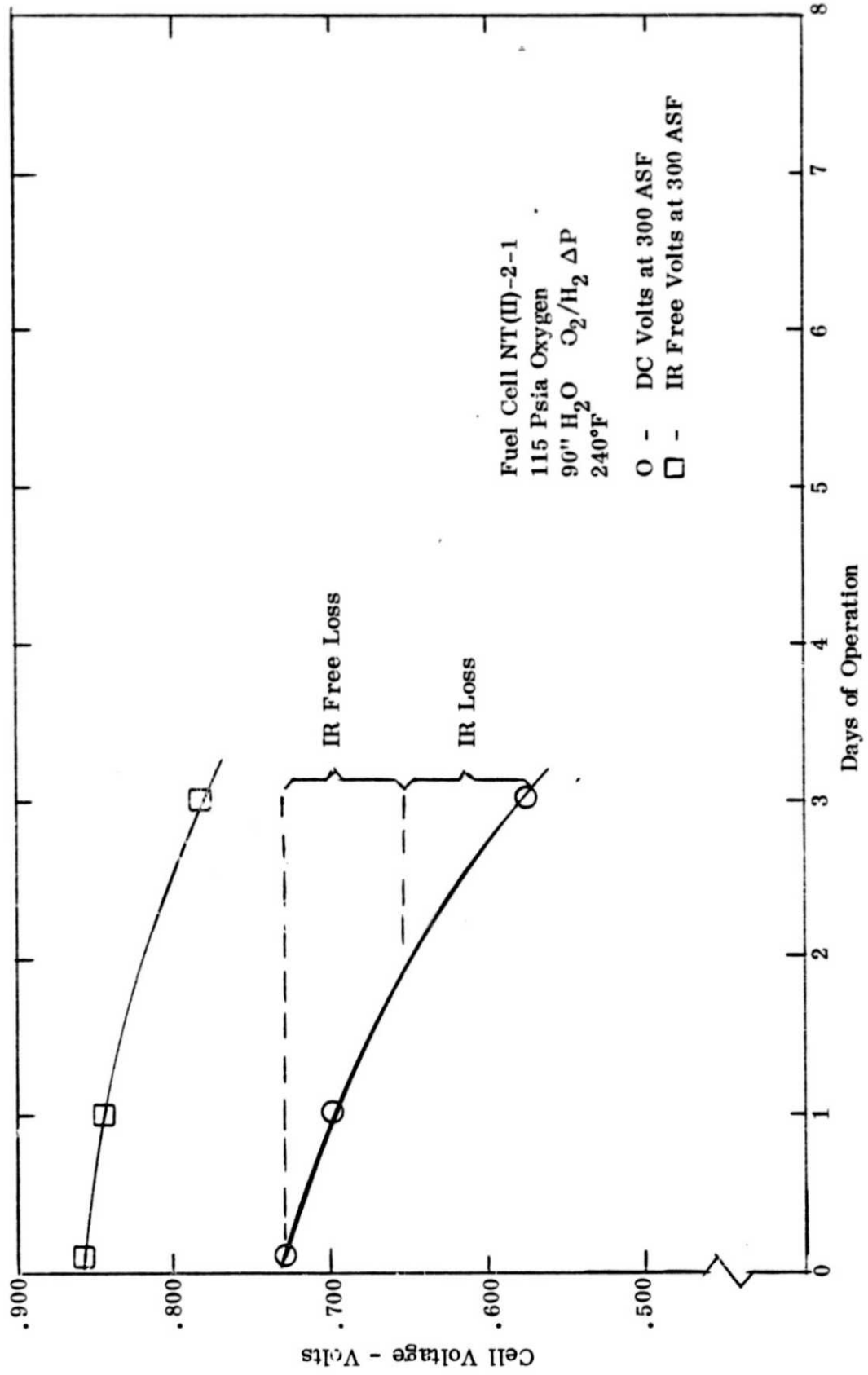

IR Free Loss
IR Loss
Fuel Cell NT(II)-2-5 115 Psia Oxygen
90" H_2O O_2/H_2 ΔP
240°F
O DC Volts @ 300 ASF
□ IR Free Volts @ 300 ASF
Cell Voltage - Volts
1.000
.900
.800
.700
.600
.500
1
2
3
4
5
6
7
8
9
Days of Operation

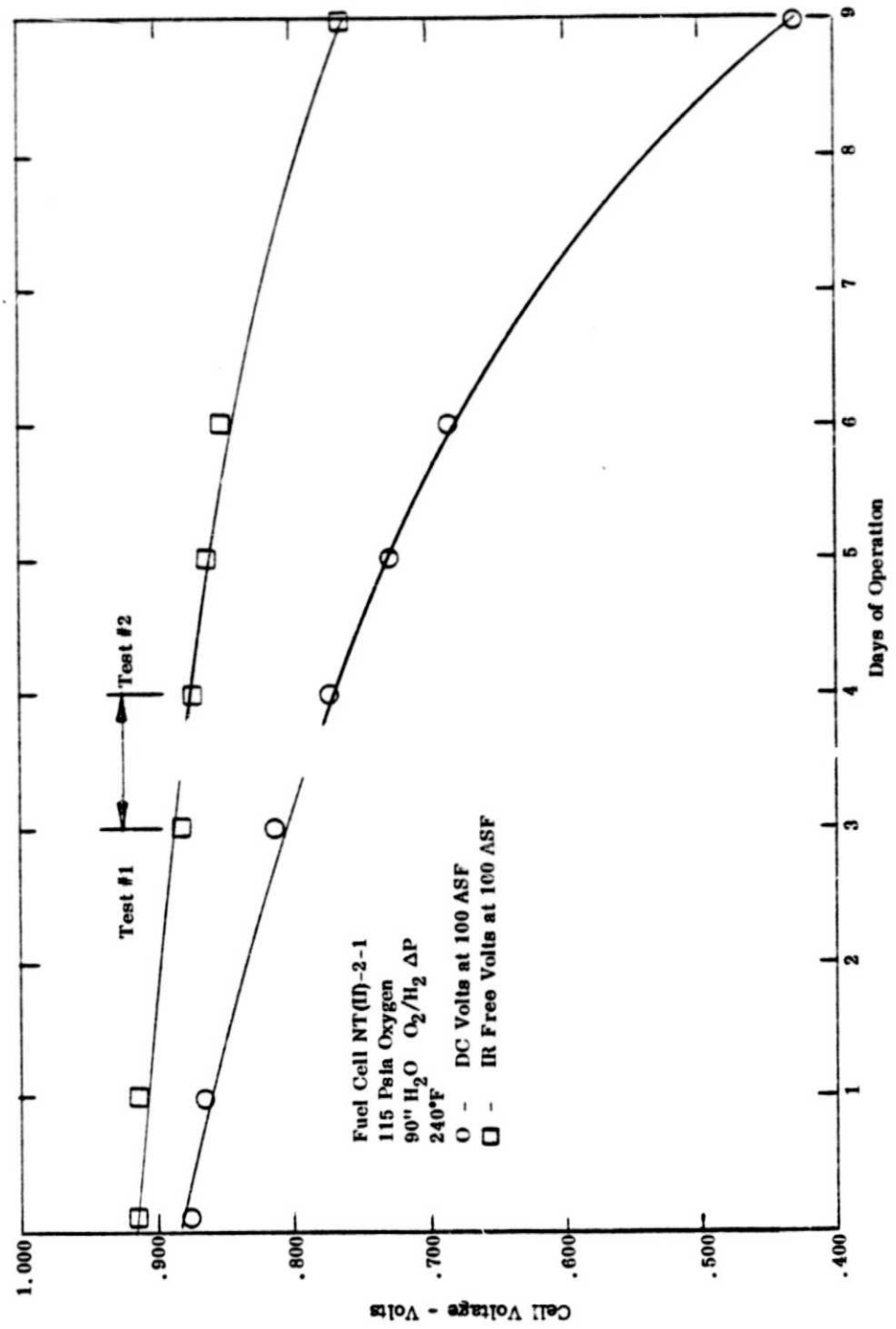

Fuel Cell NT(II)-2-4
115 Psia Oxygen
90° H_2O O_2/H_2 ΔP
DC Volts @ 300 ASF
IR Free Volts @ 300 ASF
Cell Voltage - Volts
1.000
.900
.800
.700
.600
.500
120
140
160
180
200
220
240
260
Temperature - °F


Fuel Cell NT(II)-2-4
115 Psia Oxygen
90" H_2O O_2/H_2 ΔP - 240°F
O DC Volts @ 300 ASF
□ IR Free Volts @ 300 ASF
IR Free Loss
IR Loss
Cell Voltage - Volts
1.000
.900
.800
.700
.600
.500
Days of Operation
1
2
3
4
5
6
7
8


Fuel Cell NT(II)-2-2
115 Psia Oxygen
90" H_2O O_2/H_2 ΔP
O DC Volts @ 300 ASF
□ IR Free Volts @ 300 ASF
Day 1
Day 2
Cell Voltage - Volts
1.000
.900
.800
.700
.600
.500
Temperature - °F
160
180
200
220
240
260
280
300


IR Free Loss
IR Loss
Fuel Cell NT(II)-2-2
115 Psia Oxygen
90° H_2O O_2/H_2 ΔP
240°F
□ DC Volts @ 300 ASF
○ IR Free Volts @ 300 ASF
Days of Operation
Cell Voltage - Volts
1.000
.900
.800
.700
.600
.500
1
2
3
4
5
6
7
8
9


Fuel Cell NT(II)-2-1
115 Psia Oxygen
90" H_2O O_2/H_2 ΔP
240°F
O - DC Volts at 300 ASF
□ - IR Free Volts at 300 ASF
IR Free Loss
IR Loss
Cell Voltage - Volts
.900
.800
.700
.600
.500
0
1
2
3
4
5
6
7
8
Days of Operation


Cell Voltage - Volts
1.000
.900
.800
.700
.600
.500
.400
1
2
3
4
5
6
7
8
9
Days of Operation
Test #1
Test #2
Fuel Cell NT(II)-2-1
115 Psia Oxygen
90" H_2O O_2/H_2 ΔP
240°F
O - DC Volts at 100 ASF
□ - IR Free Volts at 100 ASF

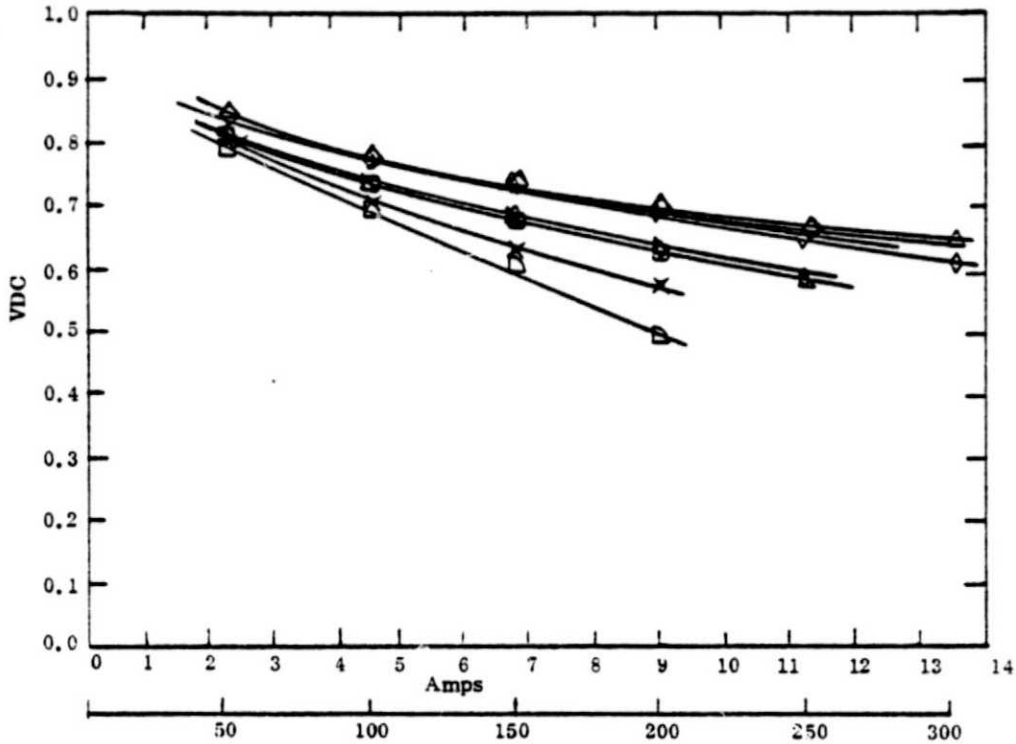
TASK 1.3 MATERIALS PERFORMANCE

PURPOSE:

To Investigate Several Materials That Have The Potential For Increasing Fuel Cell Performance And/Or Reducing Overall Fuel Cell Costs.

Two Fuel Cells Have Been Fabricated And Evaluated As Part Of This Task.

Fuel Cell Number NASA (Phase II) Technology-Subtask-Cell NT(II) - X - X	Deviation from 1975 Baseline Fuel Cell	Performance Variance from 1975 Baseline Fuel Cell: O_2/H_2 100 ASF at 120°F VDC (0.781)	O_2/H_2 200 ASF at 120°F VDC (0.703)	O_2/H_2 100 ASF at 165°F VDC (0.786)	O_2/H_2 200 ASF at 165°F VDC (0.712)	Air/H_2 100 ASF at 165°F VDC (0.736)	Air/H_2 200 ASF at 165°F VDC (0.626)	O_2/H_2 (10 PPM CO) 100 ASF at 165°F VDC (0.780)	O_2/H_2 (10 PPM CO) 200 ASF at 165°F VDC (0.695)	O_2/H_2 (.3% CO) 100 ASF at 165°F VDC (0.693)	O_2/H_2 (.3% CO) 200 ASF at 165°F VDC (0.566)
NT(II)-3-1	2 Mil Chemplast Cathode Wet-proofing	-0.044	-0.075	-0.008	-0.017	-0.045	-0.142	-	-	-	-
NT(II)-3-2	.97 IEC vs. .8 Normal	+.008	+0.020	+0.014	+0.017	-	-	-	-	-	-



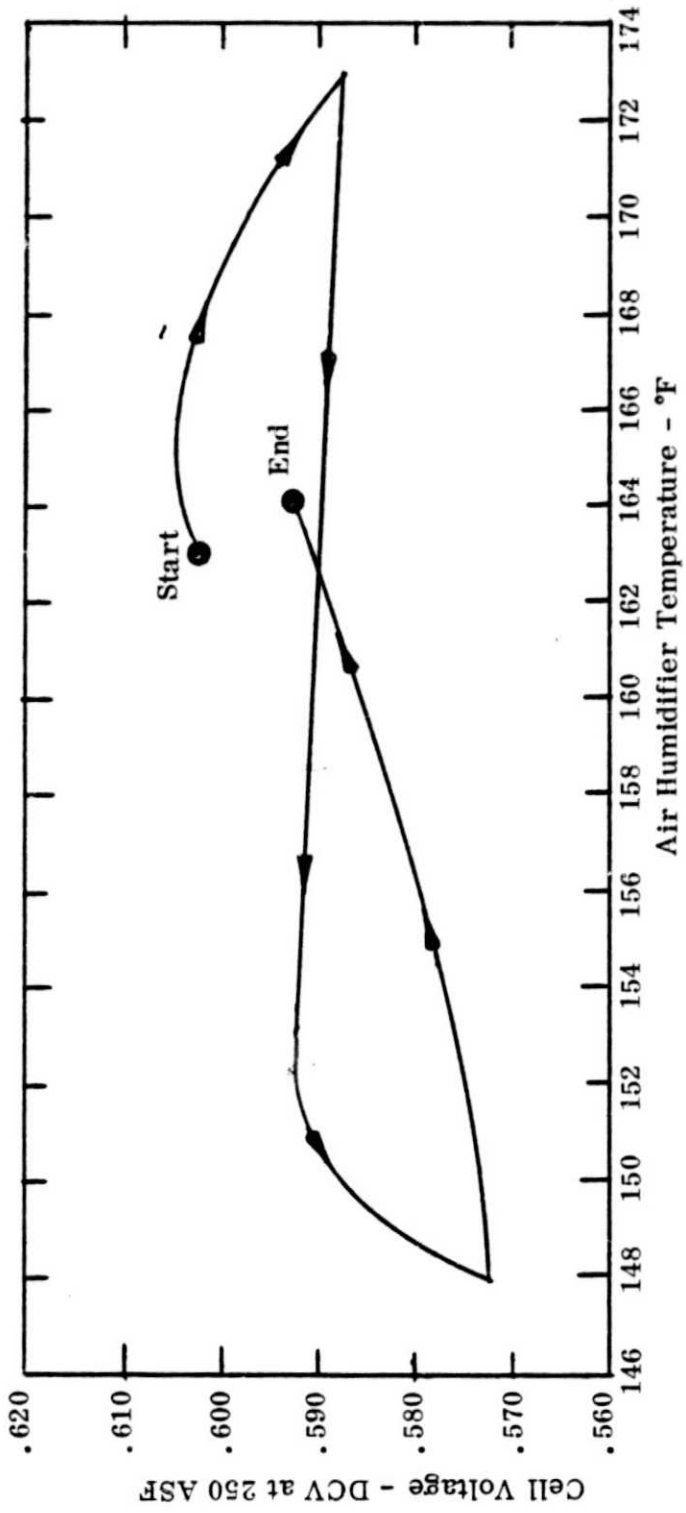
Fuel Cell NT-6-2 (1975 Baseline)

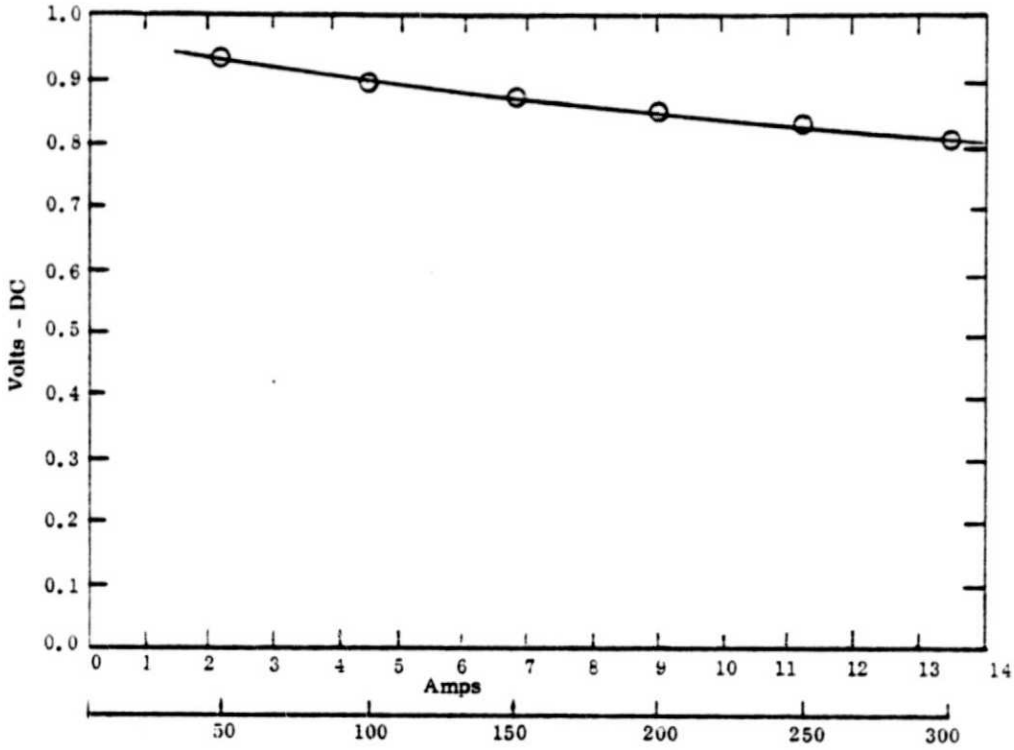
- ◇ - O_2/H_2 (120°F) R = 0.0067 Ohm
- △ - O_2/H_2 (165°F) R = 0.0065 Ohm
- □ - Air/H_2 (165°F) R = 0.007 Ohm
  2.5 x Air Stoich
- ○ - O_2/H_2 (25% CO_2 - 0.3% CO)
  1.25 x Stoich (165°F) R = 0.0065 Ohm
- ✕ - O_2/H_2 (25% CO_2 - 0.3% CO0
  1.25 x Stoich (165°F) R = 0.0065 Ohm

Fuel Cell NT(II)-3-1 (2 Mil Chemplast)

- ◺ - O_2/H_2 (120°F) R = 0.0075 Ohm
- ◊ - O_2/H_2 (165°F) R = 0.0062 Chm
- ◺ - Air/H_2 (165°F) R = 0.0062 Ohm
  2.5 x Stoich Air (Initial Performance)
- 0 - Air/H_2 (165°F) R = 0.006 Ohm
  2.5 x Stoich Air (11 Days After Start)

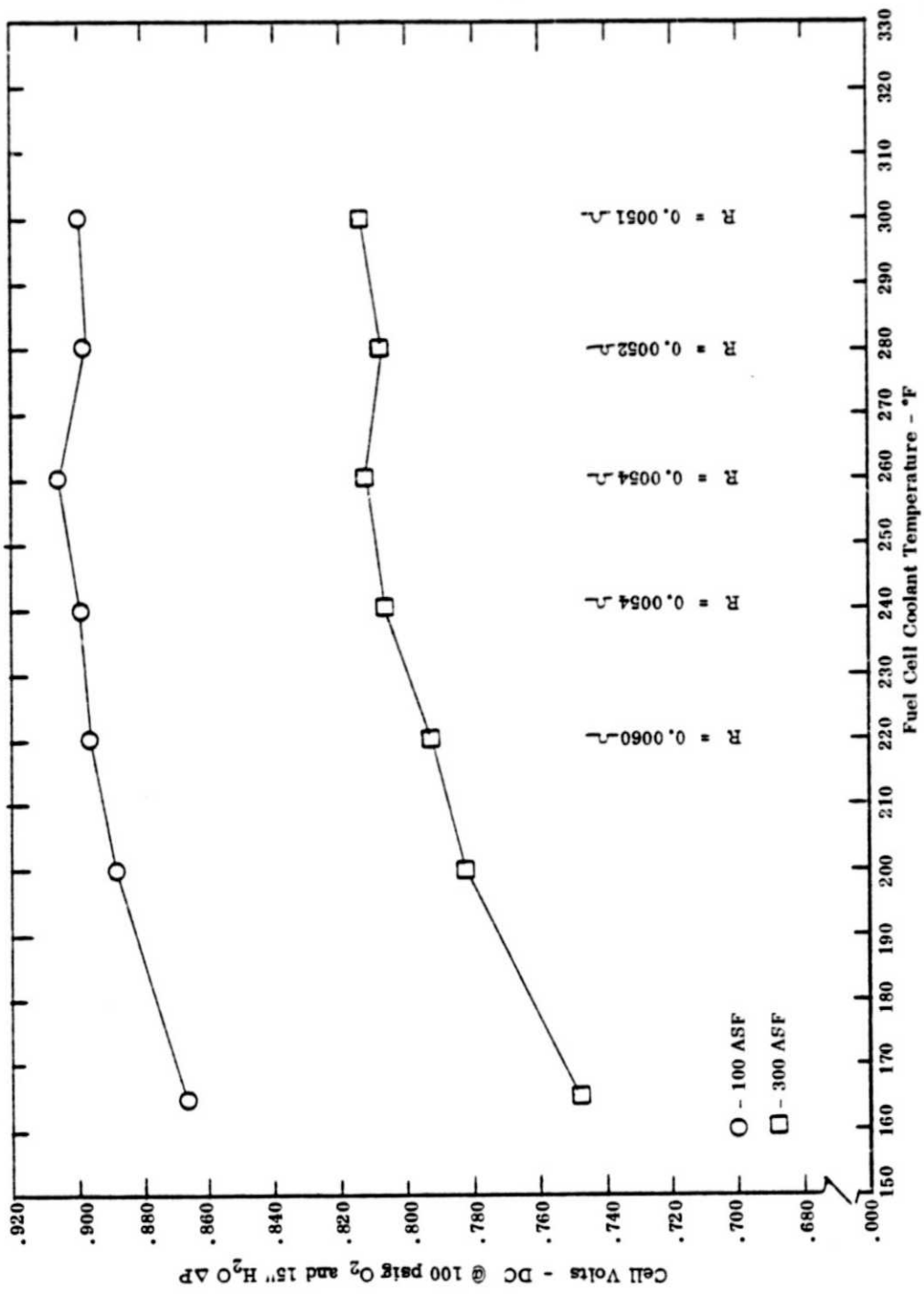
Fuel Cell NT(II)-3-1
Performance @ 165°F





Fuel Cell NT(II)-3-2 (High IEC)

○ - O_2/H_2, (300°F), 100 psig O_2, 20" H_2O ΔP
R = 0.0049 Ohm



Fuel Cell NT(II)-3-2 Performance

TASK 2.0 STACK NT-1 TEST EVALUATION

PURPOSE:

To Conduct a Thorough Performance Analysis On Single Cell Stack NT-1.

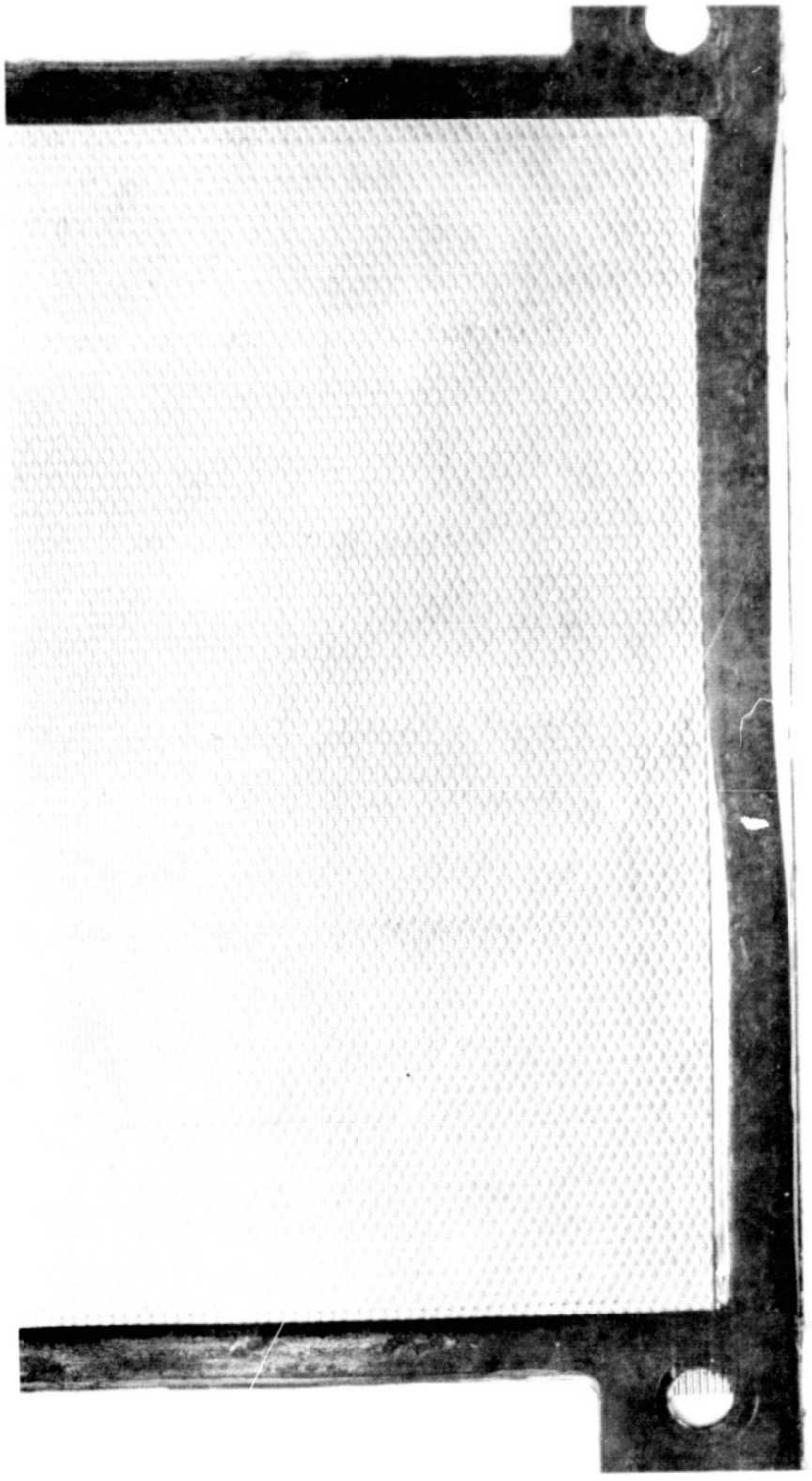
RESULTS:

- Total Of 353 Load Hours Accumulated
- May Current - 70 Amps (100 ASF)
  At 125°F and 2 Psig

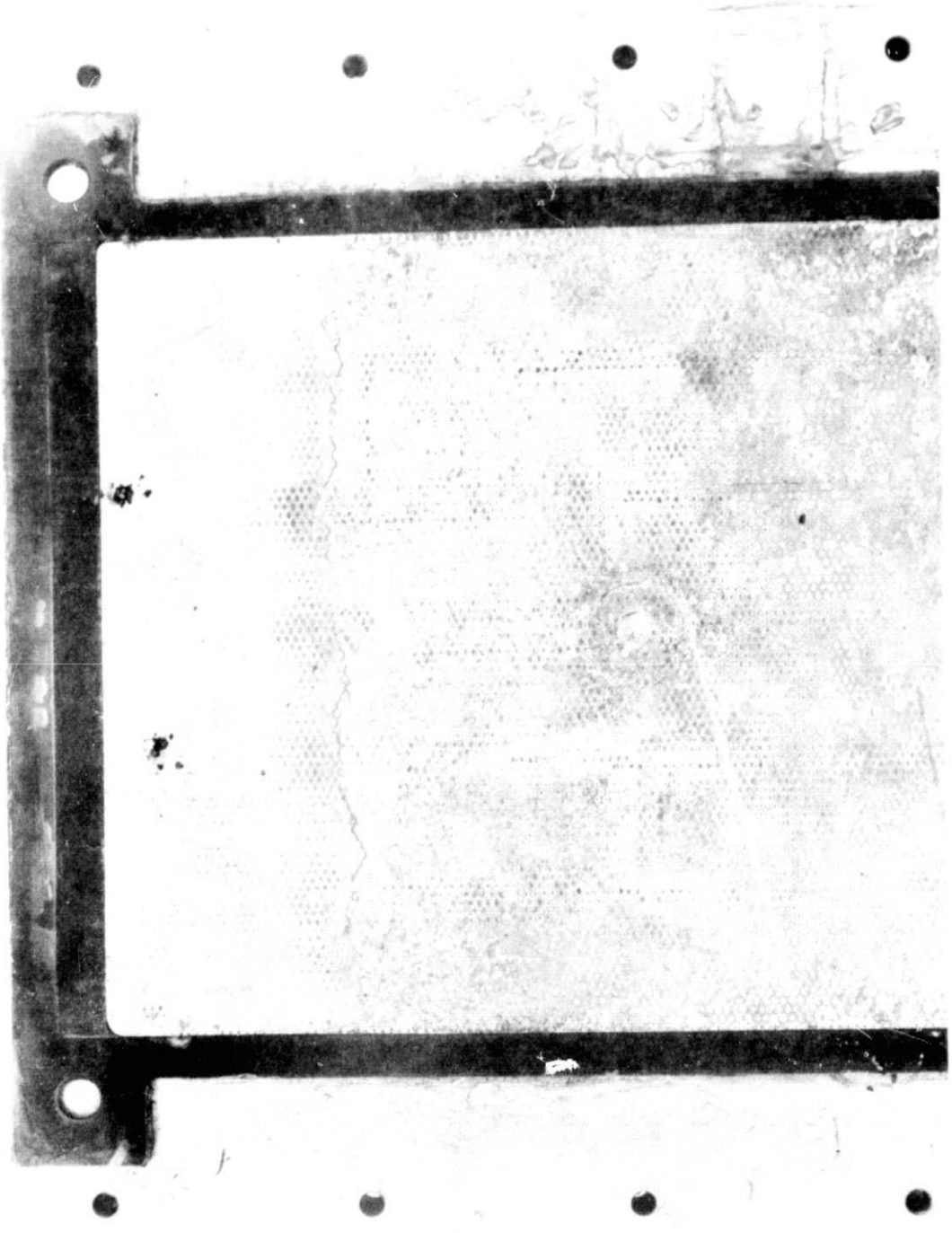
  Performance 0.67 Volt
- Two Automatic Shutdowns
  (1) Restricted Hydrogen Flow
  (2) Contact Resistance Growth

PRESENT STATUS:

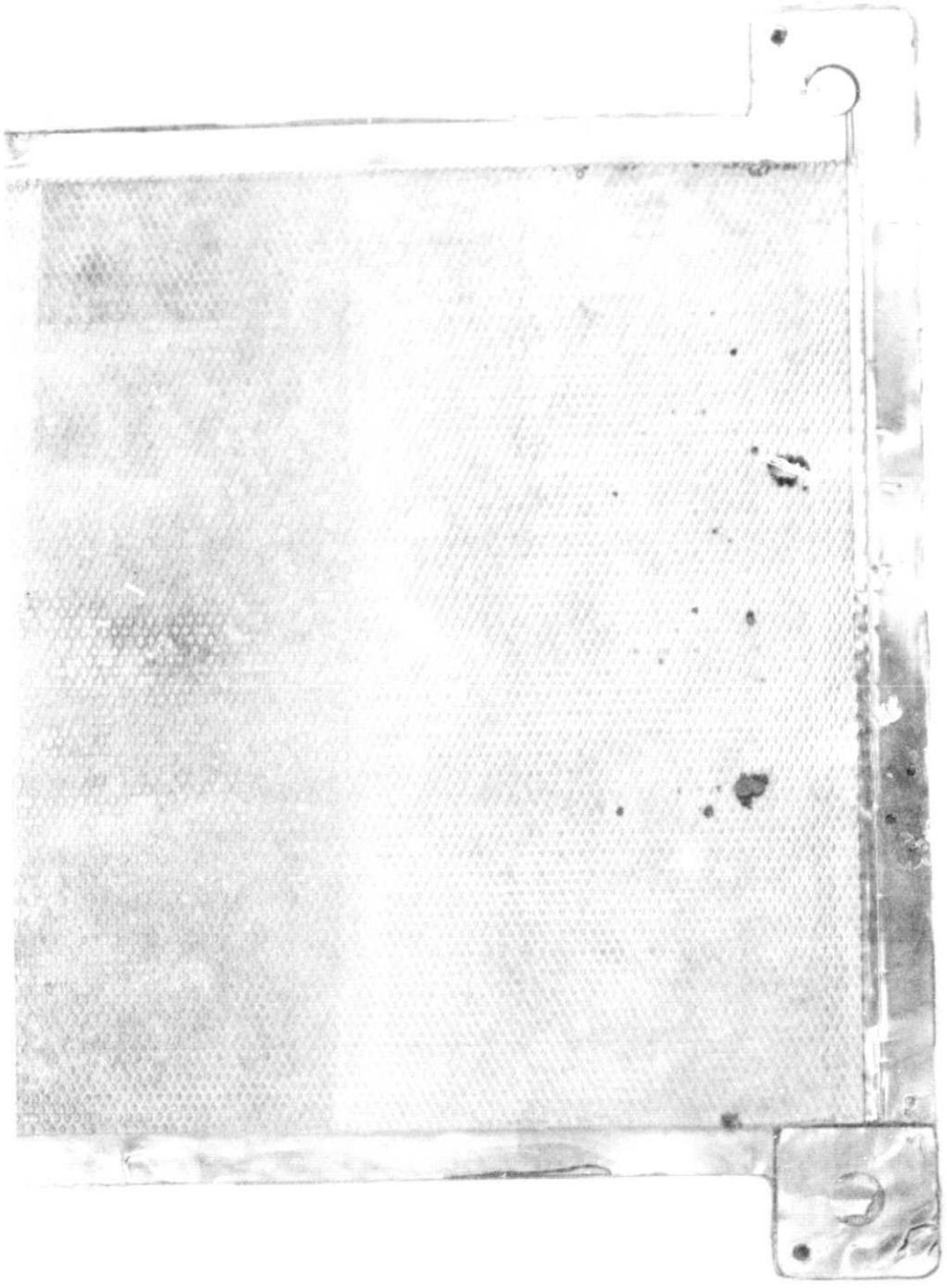
Rebuild With Corrective Actions Completed. Restart Of Test Evaluation Planned For Next Week.



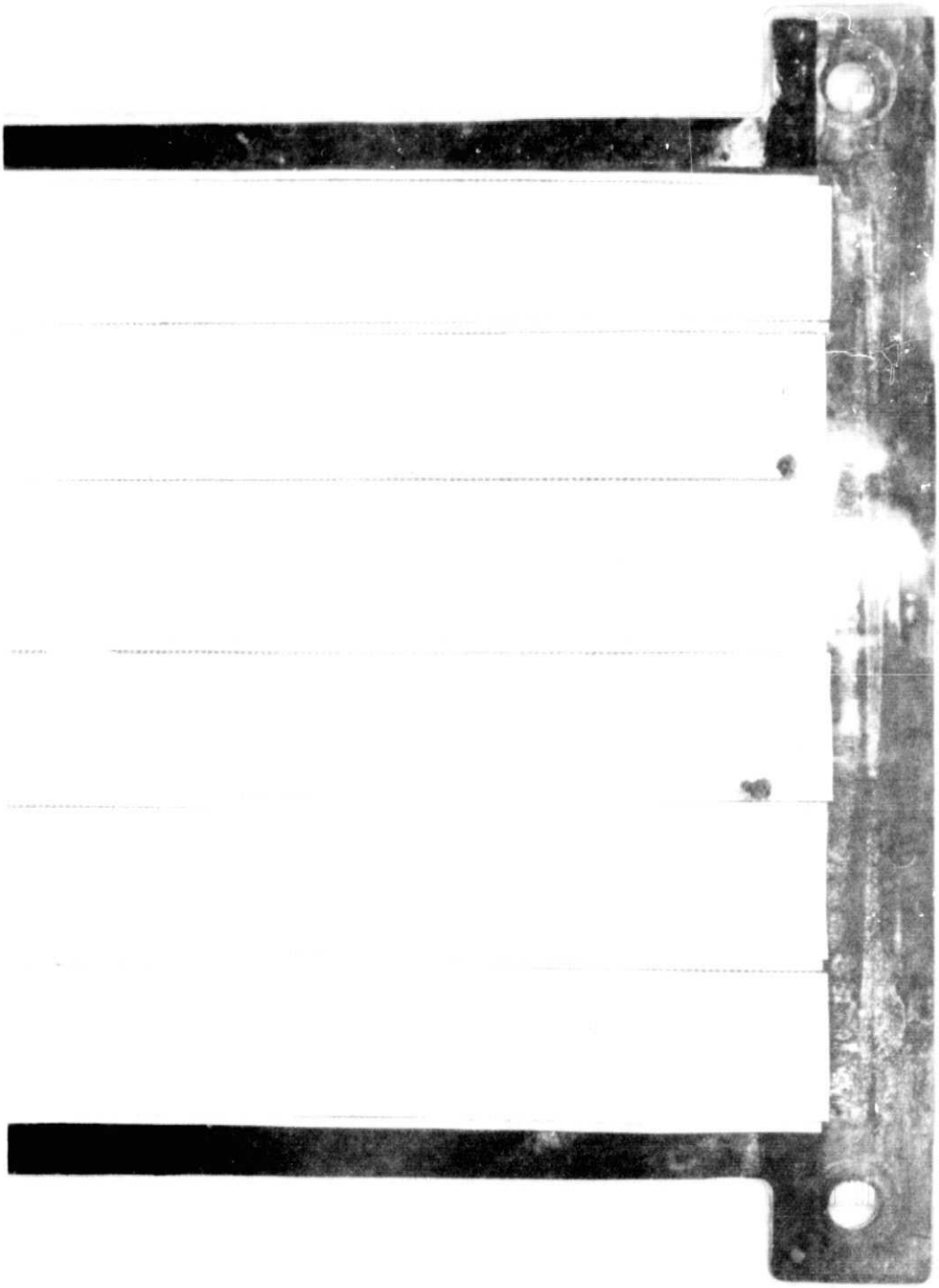
Coolant Cartridge Assembly



Oxidize Terminal Plate



Back Side of Cathode Coolant Cartridge



Cathode Side of Cathode Coolant Cartridge